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PHYSICS.—*Measure for measure: Some problems and paradoxes of precision.*[1]

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Measurements constitute such an essential part of science that I feel no apology is needed for devoting this address to a rather rambling consideration of certain aspects of the measurement process that are sometimes overlooked. Even Standen in his amusing satire *Science is a sacred cow* recognizes the importance of measurement in science by writing, "If the idols of scientists were piled on top of one another in the manner of a totem pole, the topmost one would be a grinning fetish called Measurement." Though my examples will be drawn for the most part from the physical sciences, with which I have had first hand experience, I want to stress that my theme lies not so much in physics as it does in behavioristic psychology. The whole system of concepts, units, dimensions, and standards by which measurements are made is inherently an artificial creation; a tool like the artifacts about which my predecessor, Dr. Roberts, told us a year ago, created by man in his own image (or as it often seems to the student, perhaps in the image of the devil) and hence showing many of man's peculiarities both his weaknesses and his virtues. The phrase "in his own image" applies in a literal sense to units like the foot, the cubit, and the pace. More figuratively we see his sense of humor reflected in the name "barn" recently given to a unit of 10^{-24} sq cm and used to express the effective cross-section of an atomic nucleus which the experimenter tries to hit with atomic "bullets" from his cyclotron. Man's hero-worship is shown by the use of the names of great scientists as names of units such as the ohm, ampere, henry, poise, stoke. His nationalistic prejudices have not been absent from the discussions which precede the adoption of such nomenclature.

The value of measurement is not limited to the obvious fields of scientific research, engineering development, control of manufacturing process and the commerce of the market place. Each individual needs a certain amount of quantitative knowledge as a basis for the conduct of his daily life, for the appreciation of the world about him, and for the appraisal of his fellow men and their achievements. Many of our present difficulties, I believe, arise from a lack of quantitative realization by many persons, of the labor equivalent of a billion dollars, the energy equivalent of an atomic bomb, the dimensions of the Siberian steppe or of the Atlantic Ocean.

CLASSIFICATION OF SCALES

One definition of "measurement" is "the establishment of a one-to-one relationship between the quantity or phenomenon being measured and a number." The value of measurement arises because of the very useful properties possessed by numbers such as identity (e.g., 3 is different from 2), order (e.g., 3 follows 2), size (e.g., 3 is larger than 2), obedience to the rules of arithmetic, algebra, and so on. Here I am using "number" in a rather general sense, for while measurements are commonly expressed by the sequence of real numbers, certain kinds of quantity common in electrical engineering require the use of complex numbers, many quantities in physics require vectors and some quantities require tensors. It should never be forgotten that a numerical measurement is of value *only* to the extent that the

[1] Address delivered February 15, 1951, as retiring president of the Washington Academy of

quantity measured also possesses that particular property of numbers which is to be used. Thus if identity is the only property of the quantity concerned, one must not use addition. You have all heard of the sea captain confronted with a sick seaman whose symptoms, according to the instruction book, called for medicine no. 11. Bottle no. 11 unfortunately happened to be empty, so the captain made up a potion by adding a dose from bottle no. 5 to one from bottle no. 6. As an example in the other direction, consider the electrical engineering student when he first discovers that three terminals A, B, C, may be so energized that his voltmeter shows 110 volts between A and B, 110 volts between B and C, and also 110 volts between C and A. He should not be discouraged at this paradox but instead should recognize that his alternating voltages cannot be characterized merely by their magnitude. Account must also be taken of their time-phase relations as well. Hence they require not merely real numbers but the combination of real and imaginary components and therefore he should apply the rules developed by the mathematicians for such complex quantities, nowadays called "phasors."

Stevens (*1*) has systematized the classification of scales of measurement as shown in Table 1. The third and fourth column list the mathematical and statistical processes applicable to each type of scale, and it is only at his "ratio scale" that we get what is ordinarily thought of as a true measurement.

The ordinal scales, however, are not to be despised. Some, such as the Moh scale of hardness which runs from 1 for talc to 10 for diamond, and the triboelectric series, which tries to express the relative polarities of the electric charges produced by friction between different substances, are relatively vague and indefinite. Others, such as the number scales of the wire and sheet-metal gages, are quite definite, though usually purely arbitrary. A partial exception is the Brown and Sharpe (or Amer. wire gage) in which the diameter, d_n, in mils is related to the gage number n by the rather complicated formula

$$d_n = 5(\sqrt[39]{92})^{(36-n)}$$

TABLE 1.—A CLASSIFICATION OF SCALES OF MEASUREMENT

Measurement is the assignment of numerals to objects or events according to rule. The rules and the resulting kinds of scales are tabulated below. The basic operations needed to create a given scale are all those listed in the second column, down to and including the operation listed opposite the scale. The third column gives the mathematical transformations that leave the scale form invariant. Any numeral, x, on a scale can be replaced by another numeral x' where x' is the function of x listed in column 3. The fourth column lists, cumulatively downward, some of the statistics that show invariance under the transformations of column 3.

Scale	Basic empirical operations	Mathematical group-structure	Permissible statistics (invariantive)	Typical examples
NOMINAL	Determination of equality	Permutation group $x' = f(x)$ where $f(x)$ means any one-to-one substitution	Number of cases Mode Contingency correlation	"Numbering" of football players Assignment of type or model numbers to classes
ORDINAL	Determination of greater or less	Isotonic group $x' = f(x)$ where $f(x)$ means any increasing monotonic function	Median Percentiles Order correlation (type O)	Hardness of minerals Quality of leather, lumber, wool, etc. Pleasantness of odors
INTERVAL	Determination of equality of intervals or differences	General linear group $x' = ax + b$	Mean Standard deviation Order correlation (type I) Product moment correlation	Temperature (Fahrenheit and Centigrade) Energy Calendar dates "Standard scores" on achievement tests (?)
RATIO	Determination of equality of ratios	Similiarity group $x' = ax$	Geometric mean Coefficient of variation Decibel transformations	Length, Weight, Density, Resistance, Etc. Pitch scale (mels) Loudness scale (sones)

Just why our ancestors chose these particular numbers remains a mystery, but the functional relationship is quite definite and often useful. Its persistence in competition with still more handy alternatives such as $d_n = (10)^{(50-n)/20}$ is a good example of human conservatism.

Another example of what is still primarily an ordinal scale is the geologic time scale. It is true that by tree rings some 2,000 years can be counted absolutely, and by analyses for C^{14} in organic materials good approximations can be pushed to some 20,000 years. Yet this interval is so short as to be an almost negligible part of the probable 10^9 years since archeozoic times. However, the relative order of superposition of the various geological formations constitutes the primary key for unlocking the riddle of the rocks and is fundamental to the whole science of geology.

TEMPERATURE SCALES

The history of the various temperature scales illustrates the transition from an ordinal to a ratio scale. To determine whether one body is hotter or cooler than another by a more certain method than merely touching them, the basic criterion is that heat will always tend to flow from the hotter to the colder. This criterion automatically sets up an ordinal scale. To be more quantitative, the early workers chose some particular property (length, volume, or vapor pressure) of some particular thermometric substance (brass, mercury, or alcohol) as a basis for assigning numbers to a succession of thermal states and thus establishing a complete ordinal scale. However, even if two such scales based on different properties or substances are adjusted to coincide at two points; say the freezing and boiling points of water, it does not follow that they will coincide at intermediate points. It is easy to compare the first and the twelfth inches on a foot rule by sliding an auxiliary fixed interval from one end to the other, but there is no corresponding way to compare the temperature interval from 32°F to 33°F with the one from 211°F to 212°F. Warming a piece of copper wire from 30.5°F to 31.5°F causes an increase in its resistance which is almost exactly equal to the increase caused by warming it from 31.5°F to 32.5F. In contrast, the effects of warming a mass of H_2O through these two temperature intervals are startlingly different. In general, the use of a different thermometric substance, or of a different property of the same substance will lead to a scale which will differ somewhat in the numerical value assigned to any particular thermal state.

However, many properties of many substances show fairly gradual changes of property with temperature, and abrupt changes like the melting of ice occur only at a few temperatures with any one substance. Hence, a scale limited in its definition to ranges in which changes of state of the thermometric substance do not occur can be used in practice as an interval scale. The older Fahrenheit and Centigrade scales, while strictly speaking merely ordinal, are in practice used as interval scales. Until one has a true ratio scale, however, there is no significance in the old question, "How cold is twice as hot as 10° below zero?"

Kelvin recognized a hundred years ago that the dependence of a temperature scale on particular substances could be avoided by basing the scale on Carnot's principle. This principle states that the efficiency of a heat engine operating on a reversible thermodynamic cycle between two heat-reservoirs, depends solely on the temperatures of the reservoirs and does not depend on the size of the engine or the nature of its working fluid. For his first type of thermodynamic scale Kelvin (*2*) postulated that "a unit of heat in descending from a body A at temperature T° of this scale, to a body B at the temperature (T-1)° would give out the same mechanical effect, whatever be the number T." By a suitable choice of the amount of "mechanical effect" derived per "unit of heat" (i.e., the efficiency) which is to correspond to 1° on the new scale and by making an arbitrary choice of the thermal state to which the number 0 is assigned, he set up a thermodynamic scale on which the ice point and boiling point were 0° and 100°, respectively. This first Kelvin scale, however, has little similarity to the ordinary Centigrade scale and did not come into general use. Later Kelvin

introduced an alternative postulate, that the efficiency of an ideal reversible Carnot engine is equal to the quotient of the difference in the temperatures of the two reservoirs divided by the temperature of the hotter. Kelvin chose arbitrarily to make the temperature difference between the ice and steam points exactly 100°. Experiments have shown that on this scale the ice point is close to 273.16°. It has been suggested by Giauque (*3*) that it might be better to make the arbitrary choice that of a value, say 273.16°, for the ice point and in consequence to let the interval between the steam and ice points become subject to experimental determination and no longer be exactly 100°. This change is under serious consideration, but has not yet been adopted. This second Kelvin scale, because of the form of its definition, is truly a ratio scale, and there is real significance in applying the rules of arithmetic and algebra to the numerical values on this scale in thermodynamic analyses. The first Kelvin scale, defined by $L = 738 \log_{10} T\text{-}1798$, is an interval scale.

These two thermodynamic scales offer some interesting contrasts as shown by Table 2 in which an assortment of temperatures are listed on four different scales. At high temperatures the first Kelvin scale is more crowded than the usual scales and might be useful in expressing the extreme temperatures developed within an atomic bomb. At the low-temperature end the first Kelvin scale is much more expanded and extends indefinitely toward ∞ at the cold extreme. When displayed along this expanded scale of temperature, it seems perhaps less unnatural to find in this range the many strange and novel properties of matter like superconductivity and superfluidity that recent researches have brought to light.

The principal moral to be drawn from the existence of Kelvin's first temperature scale is the debunking of the concept of an "absolute zero of temperature" as a "point" at a finite distance from the ice point and perhaps attainable by a finite human effort. Instead, there appears the prospect of an unlimited field for research containing space for any number of new phenomena and offering a perennial challenge to science.

While Kelvin's second scale is ideal from a theoretical standpoint, the experimental difficulties in gas thermometry have set limits to the accuracy with which the scale can be realized in laboratory practice. Because of the need for specifying temperatures within much narrower limits, still another scale has been set up on a purely empirical foundation. This "International Temperature Scale", officially promulgated in 1927 and revised in 1948 (*4*), is intended to represent as closely as possible the Kelvin thermodynamic scale, but is defined in terms of six fixed points (melting and boiling points of specified substances) and by the use of specified formulas and measuring instruments for the interpolation of intermediate temperatures. From the boiling point of oxygen (−182.970°C) to the freezing point of antimony (630.5°C) the interpolating instrument is the platinum resistance thermometer; from the antimony point to the melting point of gold (1063.0°C) a platinum to platinum-rhodium thermocouple is used; and above the gold point the Planck radiation law.

The 1927 wording of this scale led to the

TABLE 2.—TEMPERATURE SCALES

Fahrenheit °F	Centigrade °C	Kelvin (second) °K	Kelvin (first) °L	
+ ∞	+ ∞	+ ∞	+ ∞	
+ 5×10^8	+ 3×10^8	3×10^8	+3,000	atomic bomb
+10,337	+5,727	6,000	+ 992	sun's surface
+ 6,098	+3,370	3,643	+ 830	M.P. of tungsten
+ 2,774	+1,535	1,808	+ 606	M.P. of iron
+ 212	+ 100	373.16	+ 100	steam point
+ 32	0	273.16	0	ice point
− 371.31	− 182.97	90.19	− 355	oxygen point
− 452.11	− 268.94	4.22	−1,336	helium B.P.
− 455.62	− 270.89	2.2	−1,545	helium lambda point
− 459.58	− 273.09	0.007	−3,370	adiabat. demag.
− 459.69	− 273.16	0	− ∞	

amusing paradox that for 21 years it was officially impossible to measure the freezing point of aluminum on the International Temperature Scale (*5*). When measured with a standard resistance thermometer the freezing point of aluminum is found to be 660.01°C. Since this is above the limit (660.°C) for which the resistance thermometer was then standard, it is evident that a standard thermocouple should have been used. However, if a thermocouple is used, the freezing point turns out to be 659.87°C which is below the range over which the thermocouple is standard, and therefore neither value can be considered official.

LOGARITHMIC SCALES

When a particular quantity is of importance, and therefore has to be measured over a very wide range of values, it is frequently convenient to subject the value x of the original quantity to the mathematical transformation $y = \log (x/x_0)$, where x_0 is a fixed reference level and to use the derived quantity y, both in graphical representations to save space and in common parlance to save words. This transformation is useful in cases such as the transmission of light through a succession of filters of uniform density but differing thickness or the transmission of electrical signals along a communication circuit. Here the intensity x of the transmitted effect varies with the thickness of the filter or the distance along the line in an exponential way so that its logarithm y varies linearly with thickness or distance. The effect of an interposed filter or of inserted electrical apparatus is to reduce x by a factor and to subtract a corresponding amount from y. The convenience of combining these effects additively has led by a gradual evolutionary process which is still incomplete to the invention of the decibel, the neper and similar units for logarithmic scales. Until x_0 is fixed such logarithmic or "decibel" scales are themselves interval scales of y derived from ratio scales of x. Careless handling of decibels can lead to a minor paradox. By definition a bel in y corresponds to a change in x by a factor of 10. A decibel is one-tenth of a bel. Hence, one might conclude that a decibel was a change by one-tenth of 10 or 1, which is no change at all! More seriously, real confusion does arise because at present the word "decibel" is used with a plurality of meanings. Primarily as a pure number, one decibel is the change in the $\log_{10}x$ which corresponds to a change by a factor of $\sqrt[10]{10}$ in x ($\sqrt[10]{10} = 1.259\ldots$). Hence 10 successive steps in y each of 1 decibel will correspond to a total change in y of 10 decibels or 1 bel and thus to a factor of 10 in x. Secondly, it is common practice to state the power level in a communication or sound-measuring circuit as being so many decibels. In this phraseology, the number of decibels really expresses logarithmically the ratio of the actual electrical power to some conventionally chosen reference power level, x_0, often 1 milliwatt, but sometimes by various writers as 6, 10, 12.5 or 1000 milliwatts, and all too frequently not stated at all. Thirdly, the level of sound or noise is usually expressed as a particular number of decibels, when really this number expresses its ratio to some unstated basic reference sound level. The reference level is now pretty definitely standardized at that produced by a sound pressure of 0.0002 dyne per square centimeter at 1,000 cycles per second. It is this somewhat perverted use of "decibel" as a unit of sound level which is most commonly found in the lay press.

Another reason why logarithmic scales have been found convenient lies in the properties of the human senses (at least those of sight and hearing). Weber found experimentally that the least discernible increment Δx in stimulus is approximately proportional to the value x of the stimulus already present. Thus $\frac{\Delta x}{x} = k$. Fechner then introduced the postulate that all "least discernible increments" Δx in stimulus x corresponded to equal steps Δy in a scale of sensation, y. The combination of these relations gives

$$\Delta y = K \frac{\Delta x}{x}$$

which by integration leads to $y = K \log x + C$. Thus the decibel scale based on the purely physical stimulus turns out to offer possibilities as a scale for measuring the purely psychological quantity "sensation".

However, Fechner's postulate of forming a sensation scale by adding least perceptible increments is not the only possibility and workers in psychophysics are actively trying out experimental procedures by which sensation scales can be built up on the basis of judging equal ratios of sensations or by judging equality of fairly large increments in sensation. Unfortunately these scales do not always coincide with that based on Fechner's hypothesis and the science of psychophysics has a long way to go before it can become truly quantitative.

COLOR

Even more complicated to measure than quantities representable by vectors or tensors are complex quantities having a plurality of attributes that are different in nature. A good example is the color of an illuminated surface. Here long experimentation has shown that in any case three independent attributes are involved. In different schemes for the measurement of color, these may be chosen in different ways. In the psychological color solid all possible colors are considered as occupying points in a 3-dimensional continuum. Along one axis the attribute of lightness varies continuously from black at the bottom, through progressively lighter grays to white at the top. Around this "gray axis" the hues of the spectrum can be arranged in order with a sequence of purples bridging across from the violet to the red. For any lightness and hue there is a third radial graduation in saturation from maximally saturated colors at the extremity through less and less saturated colors to gray at the axis. The three cylindrical coordinates of a point in this solid thus can serve to measure a color.

An alternative system is shown in Fig. 1, which shows the ICI chromaticity diagram for color notation and measurement. Here the three independent variables may, very roughly, be described as measures of "redness" plotted as the abscissa, x; "greenness" plotted as ordinate, y; and "brightness", which is to be thought of as plotted perpendicular to the x-y plane and as not affecting the chromaticity. In Fig. 1 the curved outer boundary represents the locus of spectrum colors and the straight chord represents the purples obtainable by superposition in various proportions of violet and red. The diagram shown has the useful property that the color obtained by superposing any two other colors lies on the straight line which joins the two component colors. Other diagrams can be derived by linear transformations from the one shown and have other useful properties.

The paradoxical feature of this diagram lies in the fact that the standard of redness or of greenness, i.e., the points $x = 1$, $y = 0$ and $x = 0$, $y = 1$ lie outside the spectrum locus so that each of these convenient and regularly used standards for color measurements is quite literally a "light that never was on sea or land."

QUADERGY

Man is a very imaginative animal and often conjures up whimsical notions that have only the most tenuous contact with reality. Yet, if such a notion fits into the pattern of his thought habits, he may wish to measure quantitatively such an entirely imaginary concept. An example of this is found in the transmission of electrical energy in an alternating-current circuit. The transmission of energy proper results from the cooperation of simultaneous alternations of the current and of the voltage in step with one another. The resultant transfer of energy is very real, for it is the thing which nowadays in a very literal sense "makes the world go 'round." The annual bill for it in the U. S. A. is some $4-billion. However, superposed on this phenomenon, there is, except in very special cases, an additional effect often described as the presence of a spurious component of current which is pulsating 90° out of step with the pulsations of the voltage. A physicist describes this situation in realistic terms by stating that under these circumstances an additional definite fixed amount of energy is oscillating back and forth along the transmission line so as to provide the necessary energy to magnetize the motors during those times in the cycle when they need to be magnetized and going back to be restored to the generator for the intervals when the motors do not need it. The actual amount of energy involved is small, being usually of the order

of that delivered by the main energy flow in 1/240 second.

The electrical engineer, or, more specifically, the load dispatcher of a power company, looks at the matter from a very different point of view. He knows that the presence of even a small oscillating component of energy produces additional heating in his equipment, leads to far greater drops in voltage between his generators and the customers' lamps than does an equal amount of in-phase current, and requires either the installation of expensive capacitor banks or costly modifications in the design of his generators. He feels, quite justly, that the customer whose load is such as to require

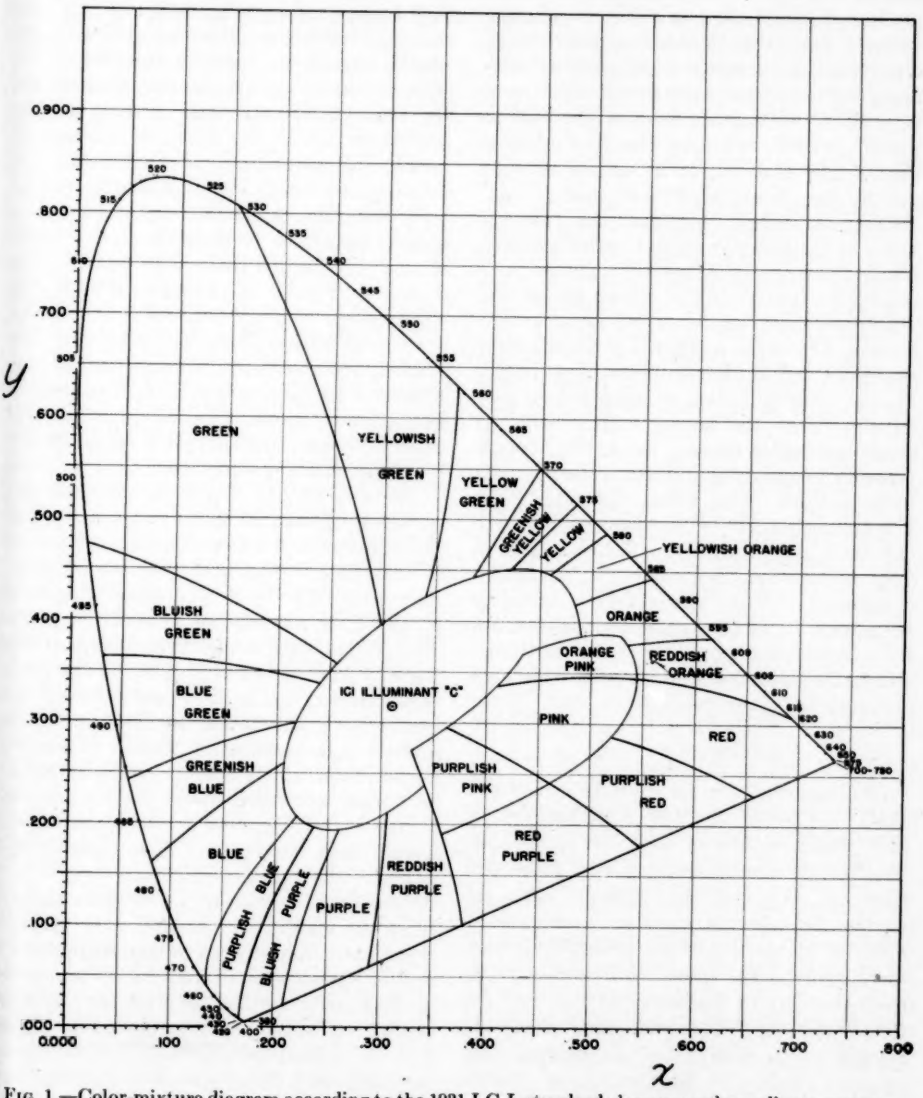

FIG. 1.—Color-mixture diagram according to the 1931 I.C.I. standard observer and coordinate system.

much of this magnetizing service should pay in proportion both to the activity of the oscillating energy required and to the time during which the service is maintained. Accordingly, he just invents a name for the product of the out-of-phase component of the current multiplied by the voltage. Many years ago in the days of the "horseless carriage" and of "wireless telegraphy" this mathematical product was called "wattless watts." But this barbarism proved too crude even for the engineers, and the more dignified term "reactive power" has come into use to distinguish it from the "active power" which measures the true average rate of flow of energy. The unit of reactive power has been christened the "var." Varmeters, which indicate the average value of reactive power, and varhourmeters, which integrate the reactive power with respect to time over the billing period and which are accurate to a few tenths of 1 percent, are on the market. Yet the quantity measured by a varhourmeter is a purely mental creation which is imagined to flow steadily from the supply circuit into an induction motor to keep it on the average properly magnetized and which the operator likes to think of as being "generated" by a static capacitor or an over-excited synchronous generator. In fact, it was only a year or two ago that they got around to christening this imaginary quantity "quadergy" and thus gave a name, if not a local habitation, to this "airy nothing" which they had been measuring with high accuracy for many years.

SYSTEMS OF UNITS

Ideal systems.—So far we have considered units and scales for the measurement of only single (simple or complex) quantities. A collection of separate unrelated units, like those of the English "system," can, of course, be used to measure a variety of different quantities. Such primitive groups of units tend to "grow up like Topsy" in each new art or industry, as witness: the denier (a size of thread such that 450 meters weigh 0.05 gram) in textiles; the printers' em; the hogshead, the turnip bushel which ranges from 42 pounds in Missouri to 50 in Tennessee and to 60 in Kentucky; a prize example of an incoherent unit actually used in certain government reports for the effectiveness of an aircraft radiator is "the Btu dissipated per minute, per inch of radiator thickness, per square foot of frontal area, per mile per hour air speed, per degree centigrade temperature difference.". The use of a set of such unrelated units requires the memorizing of a large number of numerical conversion factors. How many cubic inches in a quart? How many square yards in an acre?

In contrast to such accidental growths, the ideal would be a single system of units applicable to all branches of science, in which the magnitude of each unit was deducible by an obvious and simple relation from the units of simpler and more fundamental quantities. The metric system which sprang full-fledged from the brains of a group of French savants constitutes the outstanding example of such a coherent system of units. Here not only are the various denominations of units on any one scale related by simple decimal factors, but the units for more complex quantities are related to the more fundamental quantities by simple defining equations.

The difficulty in achieving an ideal and universal system of units in science arises not because such coherent systems are hard to construct, but because they are too easy. As a result the world is now suffering from a surfeit of alternative systems of units. The few fundamental units chosen at the start by one author may differ in size from those chosen by another (as between the centimeter-gram-second systems and the meter-kilogram-second systems). Moreover, an equation which to one person seems to be simple, convenient and the obvious one to use, may seem to another much less simple and convenient than does some different alternative equation.

Choices as to number of fundamentals.—Even the number of "fundamental" quantities chosen initially on which to build the rest of the structure is the result of a more or less arbitrary choice. In the field of electromagnetism, systems based on using 3, 4, and 5 fundamental quantities have been proposed, and many gallons of printers' ink have been wasted in arguments on which is "correct."

As a simpler example of the possibility of such alternative systems consider the unit of mass in the metric system. The gram is now defined independently and precisely as one-thousandth the mass of a particular lump of Pt-Ir alloy. The unit of force, the dyne, is then derived as a force of such magnitude that it gives to one gram an acceleration of one centimeter per second per second. Using this system of units, it is then found by the famous Cavendish experiment that two spherical masses M and M' placed a distance r center to center, will exert a gravitational force F on each other given by

$$F = G\,M\,M'/r^2 \qquad (1)$$

Here G is an experimental constant which has been found to have the value $6.6 \cdot 10^{-8}$ $cm^3/gm\ sec^2$.

This procedure seems simple and convenient to a physicist, but consider it from the point of view of an imaginary astronomer. Why drag in a particular hunk of a particular alloy? Why not set up a really simple system with only two fundamentals—length and time? Why not simplify equation (1) by setting $G = 1$ and define unit mass as such a quantity of matter that when placed one centimeter from an equal mass and then released the gravitational attraction will cause a relative acceleration of one centimeter per second per second? The unit of mass in this system is equal to $1.5 \cdot 10^7$ grams. From a purely logical standpoint, a system based on two fundamental units defined in this way is certainly simpler than the one in current use.

This kind of process can be extended further, and by using additional constants of nature such for instance as the velocity of light and the electronic charge in the same sort of way as G was used, a system can be set up in which none of the fundamental units is arbitrary or conventional. As we shall see later, the systems of units used in electromagnetism are based on processes of just this type using equations analogous to equation (1), in which numerical values, sometimes unity and sometimes other values, such for instance as $10^7/4\pi$, are arbitrarily assigned to the coefficient in the force equation.

Choices of defining equations.—An example of how diversity can result from differences in the choice of defining equations when setting up a consistent, coherent system of units from a few chosen as fundamental, can be seen by considering the simple step from length to area. At first sight it seems very obvious that if the unit of length is the inch, the unit of area *must* be the square inch. This, however, does not necessarily follow. Euclidean geometry tells us merely that for geometrically similar figures the areas are proportional to the squares of the linear dimensions; that is,

$$A = kl^2 \qquad (2)$$

We are, however, entirely free to fix the size of the unit of area, and thus the value of A for a given l by arbitrarily choosing some value for k. If we regard a square as the obvious "simplest" shape for a unit area and set $k = 1$ for this shape, we can deduce that the area A_r of a rectangle of sides a and b is $A_r = ab$ square inches and that the area A_c of a circle of diameter 1 is $A_c = \frac{\pi}{4} l^2$ square inches. This, however, is not the only "simple" procedure. The ancients certainly considered the circle as the simplest and most magically significant shape. Why should we not choose to write for the area of a circle of diameter l

$$A_c = l^2 \qquad (3)$$

In these units, the area of a rectangle becomes $A_r = \frac{4ab}{\pi}$ circular inches. This is equivalent to choosing $k = \frac{4}{\pi}$ for a square. Another possibility is to choose the equilateral triangle as the shape of the unit area for which $k = 1$. In these units if l is the length of one side, $k = \frac{8}{\sqrt{3}}$ for a square and the area of a rectangle is $8\,ab/\sqrt{3}$ triangular inches. Still another possibility might be to choose the hexagon as the unit shape. This would perhaps seem simplest to a honey bee. This makes $k = \frac{4}{3\sqrt{3}}$ for a square and the area of a rectangle becomes $\frac{4ab}{3\sqrt{3}}$ hexagonal

inches. The triangle with three sides is surely "simpler" than the square with four. Both the triangle and the hexagon, like the square can be fitted together to measure an area by the straightforward process of filling it with small tiles, each of unit area and counting the number thereof.

One of these alternatives is not a mere whimsey. In the electric cable industry, the cross-sectional areas of wires are always expressed in terms of the circular inch or the circular mil, these units being defined as the areas of circles having diameters of 1 inch and 0.001 inch, respectively. To a workman in a wire factory the use of square inches seems obviously clumsy and unnatural, nor is he at all concerned by the fact that unit circular tiles can not be fitted together to fill and thus measure an area even if it is circular.

I have stressed the arbitrariness of the choice of the square inch as opposed to the equally possible circular inch, not so much because of the industrial utility of the latter as because of the close analogy of this choice to the question of "rationalization" which has wracked the electrical art with prolonged and sometimes violent discussion for 60 years.

Eight electrical systems.—The field of electromagnetism has suffered perhaps more than any other branch of science from a plethora of "simple, coherent, logical" systems of measurement, and I shall try to outline some of the reasons for this unhappy situation.

In the early days the simplest way to define a unit electric charge seemed to be to specify that when placed unit distance away from an equal charge the force of mutual repulsion should be unity.

In other words, it seemed simplest to let $k_e = 1$ in the Coulomb force equation

$$F = k_e QQ'/r^2 \qquad (4)$$

You will see that this process is exactly analogous to that of our imaginary astronomer who set up a derived unit of mass coherent with length and time. Starting from the unit charge thus defined, the whole system of centimeter-gram-second electrostatic units has been built up by a process which welds the electrical units firmly to those of the older mechanical system, and which requires no introduction of any additional new fourth unit.

It is unfortunately equally easy to write

$$F = k_m mm'/r^2 \qquad (5)$$

for two unit magnetic poles m and m' and to choose $k_m = 1$. This gives (if r is in centimeters and F in dynes) the cgs electromagnetic system which is a perfectly good alternative system. Maxwell used both systems in his famous treatise. It can be deduced that if one sticks to either system alone, the relation $k_e k_m = c^2$ holds. Here c is the velocity of propagation of an electromagnetic disturbance in empty space. This is experimentally found to be $c = 3.10^{10}$ cm/sec i.e., the velocity of light. Other authors of theoretical treatises combine these two systems using electrostatic units for electrical quantities and electromagnetic units for magnetic quantities. This hybrid third system is called the "Gaussian System" and its use requires that the parameter c be inserted explicitly in Maxwell's field equations at the proper places.

Practical electricians, however, found it inconvenient to use units so small that it took 100,000,000 of them to equal the voltage of a voltaic cell and 1,000,000,000 of them to equal the resistance of a wire of reasonable dimensions. Under the wise guidance of Maxwell and his colleagues on a committee of the British Association for the Advancement of Science there was set up a fourth group of units called "practical" in which the units were exact decimal multiples of the corresponding units of the cgs electromagnetic system. The electrical units of this group were given individual names—coulomb, volt, ampere, ohm, henry, farad—thus immortalizing the honored pioneers of electrical science.

The experimental process by which the electrical resistance of a wire standard is determined in terms of length, mass and time is exceedingly difficult and laborious. Hence, it was only natural that our forefathers should set up "as a system of units representing the above and sufficiently near to them" still a fifth system in which the unit of resistance was defined as the resistance of a column of mercury of specified dimensions

at a specified temperature and the unit of current was that which would deposit silver from a solution of silver nitrate at a specified rate. This fifth system was christened the "International System of Electrical Units" and had legal status from 1894 to 1947. As far back as 1908 it was recognized that the "International" units differed by small but significant amounts from the practical multiples of the cgs electromagnetic units. Experimental techniques for evaluating with adequate accuracy the "true" or "absolute" values to assign to standards of resistance or of electromotive force were gradually developed; and effective January 1, 1948, the world shifted its basis back to the units of the absolute practical group. The "International System" has therefore now been a dead issue for three years. "May it rest in peace." (*6*.)

The six electrical units of the absolute practical group are simply and coherently related to each other and to the mechanical joule and watt, but the powers of 10 by which they are related to the cgs electromagnetic system are arbitrary, so that the system as a whole is not coherent. As a result, an experimenter normally makes his measurements in practical units. Then he applies the proper factors to convert his results to units of the self-consistent cgs electromagnetic system. The insertion of these values in the theoretical equations enables him to predict future phenomena quantitatively. A reconversion back to the practical units then shows him what values to expect in his later verification measurements.

By a happy coincidence there is a possibility of avoiding the necessity for these repeated conversions and for memorizing a plurality of numerical conversion factors. This was pointed out at the turn of the century by Giorgi (*7*). If one takes for the basic mechanical units the meter, the kilogram and the second, and if one assigns arbitrarily to the coefficient k_m in equation (5) the value 10^7 instead of unity, it turns out that the practical absolute electrical units automatically show up as members of the resulting self-consistent system. This sixth system in our list is labelled the "Meter-kilogram-second-ampere" or "Giorgi" system. Most writers who use this system prefer to consider it as based on four independent fundamental quantities rather than on the classical three. This is equivalent to considering that the coefficient k_m is not a pure number but that it has dimensions. In terms of length, mass, time and electric current as fundamental quantities, the dimensions of k_m turn out to be $[I^{-2}\, t^{-2}\, M^1\, l^1]$. Thus in equation (5) the arbitrary assignment of a numerical value to k_m fixes the magnitude of the unit of m and hence of the ampere and other electrical units. On the other hand, the arbitrary choice of an electrical quantity, for instance current, as fundamental, fixes the dimensions of magnetic pole strength and by way of equation (5) fixes the dimensions of k_m.

The assignment to k_m of dimensions and a value other than unity has brought forcibly into the limelight a very disgraceful situation which has existed for a long time in the field of magnetic units. The trouble shows up clearly in an equation, which can be found in almost any textbook more than fifteen years old, and which relates the magnetic induction, B, to the resultant magnetizing force, H, and the intensity of magnetization, J, at any point in a bar of iron,

$$B = H + 4\pi J \tag{6}$$

This equation may profitably be considered the definition of J. If k_m is dimensionless, B, H, and J all have the same dimensions, whether or not they are quantities of the same physical nature, and, if the magnitude of k_m is unity, then numerical values are correctly indicated by equation (6) as written. However, if k_m has dimensions and is equal to 107 we must write either

$$B = 10^{-7} H + 4\pi J \tag{7}$$

or

$$B = 10^{-7} (H + 4\pi J) \tag{8}$$

According to the former "intensity of magnetization" is defined as a quantity having the same dimensions as magnetic induction. According to the latter "intensity of magnetization" has the same dimensions as magnetizing force. There is nothing in the equations of the earlier literature which used $k_m = 1$ to indicate which concept the

writer preferred. In recent textbooks some authors use one and some the other meaning for the words "intensity of magnetization," while still others dodge the issue. The same ambiguity exists in the related concepts of magnetic moment and magnetic pole strength. Because of the differences in current usage, national and international standardizing bodies hesitate to decide the issue and in the meantime the volume of ambiguous and conflicting literature grows apace!

Still another question regarding electrical units which had been left unanswered for some 60 years is "to rationalize or not to rationalize". The word "rationalize" is here used with a highly specialized meaning which perhaps can be best understood by an analogy with the case of the circular inch as a unit of area. In passing from length to area by choosing $k = 1$ in equation (2) for the case of a circular shaped unit area the simple equation (3) resulted for circular areas in general, and as a consequence of this, the factor π appeared in the formulas which involved rectangular shapes.

Similarly the electric or magnetic field around a point charge or pole has a spherical symmetry. Hence, the setting of $k_e = 1$ in equation (4) or of $k_m = 1$ in equation (5) which relates to point charges and poles insures that π will not appear in the resulting equations for arrangements having spherical or circular symmetry such as those for the capacitance of a sphere of radius r,

$$c = \epsilon r \tag{9}$$

or for the magnetizing force at a radius r from a long straight cylindrical conductor carrying a current I

$$H = 2I/r \tag{10}$$

On the other hand, the factor π appears instead in many other formulas where it would not be expected, as in that for the capacitance between rectangular plates of area A and separation t

$$c = \frac{\epsilon A}{4\pi t} \tag{11}$$

or for the magnetizing force inside a long solenoid of square cross section wound with n turns per unit length

$$H = 4\pi nI \tag{12}$$

Heaviside pointed out that "the unnatural suppression of the 4π in the formulas of central force, where it has a right to be, drives it into the blood, there to multiply itself, and afterward break out all over the body of electromagnetic theory." As a "radical cure for this eruption of 4π's" he urged a shift to what he labelled a more "rational" set of units, and himself consistently used a "rationalized" system in which k_m was set equal to $1/4\pi$. This system of units, the seventh in our list, has been used in a number of theoretical treatises and is usually designated the "Heaviside-Lorentz" system. Its units differ by various powers of the incommensurable factor $\sqrt{4\pi}$ from those of the absolute practical system and for this reason have never come into general use.

A related procedure applicable to the MKSA system and sometimes referred to as "sub-rationalization" or "total rationalization" involves writing equation (5) in the form

$$F = \frac{1}{4\pi}\left(\frac{10^7}{4\pi}\right)\frac{mm'}{r^2} \tag{13}$$

where the quantity in the parentheses is the reciprocal of what is usually called the "permeability of space." The resulting system of units, the eighth on our list, is designated the "rationalized MKSA" or the "rationalized Giorgi" system. The International Electrotechnical Commission, which in 1935 had voted its approval of the Giorgi system, took the further step in July 1950 of adopting this form of rationalization.

Recent developments in the radio field have brought the practical engineer and laboratory worker into much closer contact with the theorist and pedagogue than ever before, to the great benefit of both. The rationalized MKSA system offers advantages to both, which I believe will suffice to bring it into very general use in the electrical field in the not very distant future. It can

easily be extended to cover all branches of physical science. A name, "newton," has been assigned to its unit of mechanical force, but I have seen no indication that it is displacing the entrenched cgs units in theoretical mechanics or those of the mechanical engineers' units based on the kilogram force.

CLASSIFICATION OF STANDARDS

The various ways that have been or are currently in use for defining units of measurement fall naturally into a number of classes. In early work, individual or personal standards were used such as Galileo's pulse, with which he timed the pendulous swings of the chandelier in the cathedral of Pisa; Fahrenheit's body temperature, which fixed the 100° point on his original temperature scale; the pieces of iron and brass wire used by Ohm; the foot; the pace; and, all too often even in current publications, a millimeter deflection of an undefined galvanometer of unspecified sensitivity. Following these, came particular artifacts such as bronze cubits, intended to embody the length of the king's arm, and perhaps some dimensions incorporated in the Egyptian pyramids. The supreme examples of such artifacts are the standard prototype meter and kilogram, which now repose in the vaults at the International Bureau of Weights and Measures.

To secure reproducibility, however, definitions based on natural objects have frequently been used. Examples of such are the barley-corn, and at the other extreme, the earth-quadrant, which was originally used in the definition of the meter, and our present time standard, the rotation of the earth. In a slightly different category are definitions based on the physical or chemical properties of specific substances. In this class were the definition of the International Ohm as the resistance of a specified column of mercury and that of the International Ampere as the electric current which would produce electrochemical action at a specified rate. The fixing of the kilogram by the density of water and the setting up of a thermometric scale by the relative thermal expansion of mercury and glass and by the use of standard melting and boiling points are other examples. The old definition of the curie as the unit of radioactivity also comes in this category, because it was the activity of a specified amount (1 gram) of a specified aggregation of substances.

A still different category is the use of the properties of individual atoms as distinct from the properties of matter in bulk. Thus, the new curie and the rutherford, defined as the activity corresponding to 3.700×10^{10} and 10^6 atomic disintegrations per second respectively are philosophically distinct from the old curie. In this atomic class are the use of the wave lengths of cadmium radiation or more recently of that from the mercury 198 isotope as standards of length, and the frequency of oscillation of the ammonia molecule in the "atomic clock" (*8*).

EVOLUTION OF UNITS

In all fields there have been in progress evolutionary shifts in the choice of units. The parallel developments of the electrical units and that of the temperature scale illustrate this. In both fields, the early workers used measuring schemes based on properties of matter such as thermal expansion of mercury in glass on the one hand, and the electromotive force of particular voltaic cells on the other. Theoretical relations were then worked out and resulted in the Kelvin thermodynamic temperature scale and the cgs electromagnetic and electrostatic unit systems of Maxwell. In each field, however, the need for higher precision than could be obtained in the experimental realization of the theoretical units forced the introduction of an auxiliary system based again on the properties of matter in bulk. These auxiliary systems, the "International" electrical units and the "International Temperature Scale" formed the basis for all precise scientific measurements as well as for commercial operations, although the theoretical unit systems continued to be recognized in parallel with them as being of an even higher echelon. The electrical art has finally reached a level where the theoretical system can be realized experimentally with an accuracy at least comparable with that attainable with the auxiliary system and has therefore sloughed off the latter. The temperature scale has not yet reached this

enviable position, but perhaps will do so in the not too distant future.

The evolution of the units of length and mass have followed a somewhat different pattern. At the introduction of the metric system, the earlier arbitrary units embodied in artifacts were displaced by the units based theoretically on the earth-quadrant and the density of water. As in the other fields, the demand for ever increased accuracy forced the abandonment of the theoretical values for an auxiliary system which in this case consisted of two simple artifacts, the prototype standard meter bar and the prototype kilogram mass. There is now pending a shift of the unit of length to an atomic basis, the wave length of radiation from Hg^{198}, but it will probably be a long time before techniques for counting individual atoms can be developed to their logical climax of enabling the mass of the proton to be used as a practical standard.

The measurement of time has shown a still different history. The habits of mankind are so closely geared to the astronomical periodicities that from earliest antiquity the unit of time has been based on the rotation of the earth. The recent development of "atomic" clocks, the unit of which is based on some natural molecular frequency, such as that of ammonia, offers the first significant departure from this basis. However, it seems safe to predict that no matter how rapid and successful the evolution of a laboratory time system based on atomic units may be, and no matter what vagaries it may show to exist in the motion of the earth, there will always be, in common use, an astronomical time system based on the mean solar day.

I hope that I have shown that the process of measurement is, after all, a very human activity; that in it may be found illustrations of the foibles as well as the wisdom of *Homo sapiens;* that units are unfortunately not fixed, immutable creations of nature, but merely human constructs; that there is a real progression in the evolution of systems of measurement; and that their present imperfections should be a challenge to the scientists of the future.

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MATHEMATICS.—*A problem in geometric probability.* JEROME CORNFIELD and HAROLD W. CHALKLEY, National Cancer Institute. (Communicated by Richard K. Cook.)

1. INTRODUCTION

We have recently published a description of a method for estimating volume-surface ratios for closed 3-dimensional figures of arbitrary shapes (*1*). The method involves throwing a line of fixed length, r, at random in a space containing the figure. We count the number of times either of the two end points fall in the interior of the figure, and denote it by h for hits, and the number of times the line intersects the surface of the figure and denote it by c for cuts. The method depends upon the fact that

$$r\,\frac{E(h)}{E(c)} = 4\,\frac{V}{S}. \tag{1.1}$$

where V is volume and S is surface and E stands for expected value.

We note that (1.1) holds for reentrant as well as nonreentrant figures and is consequently more general than the nonparametric relationships of this type, such as Crofton's (*2*), that have been previously established. This note is devoted to a proof of (1.1).

2. A DEFINITION OF A RANDOMLY THROWN LINE

In what follows we assume that in throwing a line of length r at random (a) there is a uniform probability that one end point, P, will take on any position in the space and

(b) there is a uniform probability that the other end point, P^1, will take any position on the surface of a sphere with center at P and radius r. This is an obvious generalization of the assumptions usually made in problems of geometric probability in two dimensions, e.g., in Buffon's needle problem. We have presented evidence elsewhere (*1*) which indicates that this appears to provide a satisfactory description of the physical process of throwing a line at random.

3. THE EXPECTED VALUE OF THE NUMBER OF HITS

We shall show

$$E(h) = \frac{2Vn}{X}, \tag{3.1}$$

where X is the volume of the space in which the line segment falls and n is the number of throws. Because there are difficulties in visualizing the necessary three dimensional figure, we shall begin with the two dimensional problem.

We start with a closed figure, F, of area A in a square of side $X^{1/2}-2r$ (Fig. 1). The end point of the line segment, P, will occupy with uniform probability all positions in the square of side $X^{1/2}$. Since the angle that the line segment makes with the X axis, θ, varies from 0 to π, the point, P^1, will occupy all but some corner positions in the square of side $X^{1/2} + 2r$.

If we consider fixed values of y and θ, the probability that the point P will fall inside the figure is $f(y)/X^{1/2}$, where $f(y)$ is the width of the figure at ordinate y. (For values of y falling outside the figure $f(y) = 0$.) Similarly, the probability that for fixed values of y and θ the point P^1 will fall inside the figure is $f(y, \theta)/X^{1/2}$. If we now let y vary from 0 to $X^{1/2}$, but hold θ fixed, we have

$$\begin{aligned} \text{Prob. } (P \in F) &= \frac{1}{X}\int_0^{X^{\frac{1}{2}}} f(y)\,dy \\ \text{Prob. } (P' \in F) &= \frac{1}{X}\int_0^{X^{\frac{1}{2}}} f(y, \theta)\,dy. \end{aligned} \tag{3.2}$$

Each integral, obviously, is an expression for the area of the figure, A, and is consequently independent of θ. In n throws, therefore, the expected number of hits by either the point P or the point P^1 is An/X. Since the expected value of a sum is the sum of the expected values, the expected number of hits counting both end points is $2An/X$.

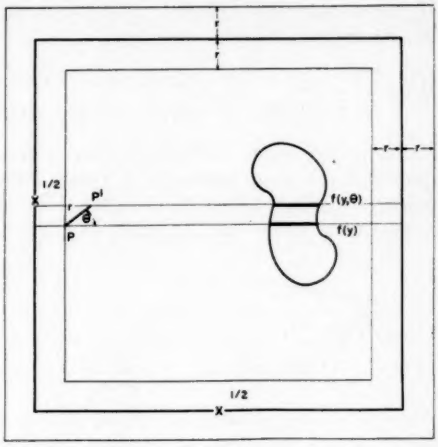

FIG. 1

The proof for three dimensions is identical except that for the point P we must consider the probability that it is included in F for fixed values of z, the additional dimension, as well as y. Similarly for the point P^1 we must consider the probability that it is included in F for fixed values of ϕ, the angle with the z axis, as well as θ. We then have

$$\begin{aligned} \text{Prob. } (P \in F) &= \frac{1}{X}\int_0^{X^{\frac{1}{3}}}\int_0^{X^{\frac{1}{3}}} f(z, y)\,dy\,dz \\ \text{Prob. } (P' \in F) &= \frac{1}{X}\int_1^{X^{\frac{1}{3}}}\int_1^{X^{\frac{1}{3}}} f(z, y, \phi, \theta)\,dy\,dz \end{aligned} \tag{3.3}$$

where each integral is an expression for the volume of the figure, V, and is consequently independent of ϕ and θ. In that case the expected number of hits in n throws by either the point P or P^1 is Vn/X, while the expected number of hits by both is $2\,Vn/X$.

4. THE EXPECTED VALUE OF THE NUMBER OF CUTS

We may without loss of essential generality consider the surface of F as composed of m quadrilaterals of area $S_1, S_2 \cdots S_m$ with

$$S = \sum_{i=1}^{m} S_i. \tag{4.1}$$

If we denote the number of cuts on the i^{th} quadrilateral by c_i, we have

$$c = \Sigma c_i$$
$$E(c) = \Sigma E(c_i) \tag{4.2}$$

Furthermore, since a straight line and a quadrilateral can intersect at only one point, $E(c_i)$ is equal to the probability of intersection times the number of throws.

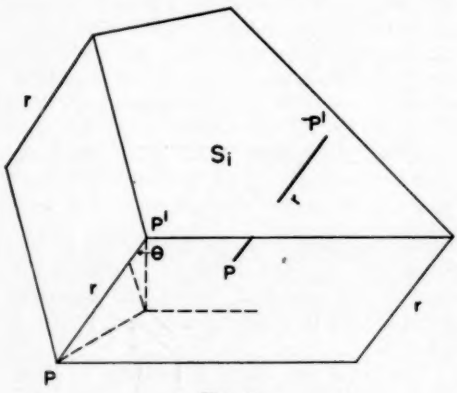

FIG. 2

If we consider the i^{th} quadrilateral, with surface area, S_i, the probability that a random line of length r will intersect it is the probability that the end point P will fall inside the parallelepiped with volume $S_i r \cos\theta$ (Fig. 2). From the preceding section this probability is

$$\frac{1}{X} S_i r \cos\theta \tag{4.3}$$

for a fixed value of θ and

$$\frac{1}{X} S_i r \int_0^{\frac{\pi}{2}} f(\theta) \cos\theta \, d\theta$$

for θ varying from 0 to $\frac{\pi}{2}$ according to the density function $f(\theta)\, d\theta$. We show in the next section that the assumptions of section 2 imply

$$f(\theta)\, d\theta = -\sin\theta \, d\theta. \tag{4.4}$$

This is the probability that a random line will form the angle θ with any other fixed line in the space. In that case

$$\text{Prob. } (P \in \text{parall.})$$
$$= \frac{1}{X} S_i r \int_0^{\frac{\pi}{2}} \cos\theta \sin\theta \, d\theta \tag{4.5}$$
$$= \frac{1}{2X} r S_i$$

and

$$E(c) = \frac{rn}{2X} \Sigma S_i$$
$$= \frac{rnS}{2X}. \tag{4.6}$$

Combining (4.6) and (3.1) we obtain (1.1).

5. THE PROBABILITY DISTRIBUTION OF θ

We wish the probability that a random line, defined as in 2, will form angle θ with a fixed line. We may take this fixed line as a radius of the sphere with center at P and radius r (Fig. 3). The probability that the line with end points P and P^1 will form an angle θ with a radius of the sphere is the probability that the end point P^1 will fall in the circumferential belt of area

$$2\pi\sqrt{r^2 - y^2}\, ds$$

where $y/r = \cos\theta$. Hence

$$\text{Prob. } (P' \in \text{circum. belt})$$
$$= f(\theta)\, d\theta = \frac{2\pi\sqrt{r^2 - y^2}\, ds}{2\pi r^2}. \tag{5.1}$$

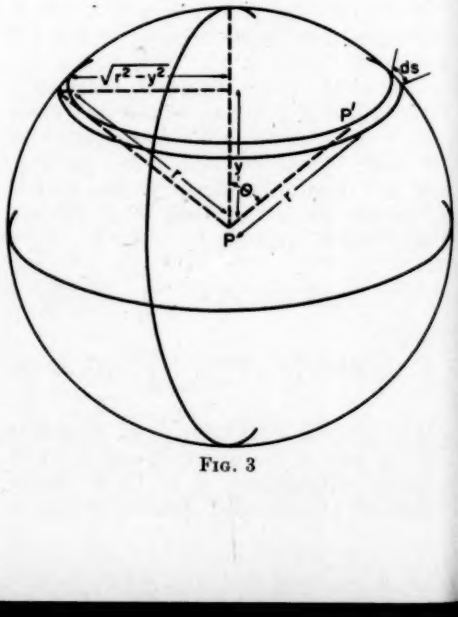

FIG. 3

It is easy to show, however, that

$$ds = -\frac{r^2 \sin\theta \, d\theta}{\sqrt{r^2 - y^2}}. \tag{5.2}$$

so that

$$f(\theta)\, d\theta = -\sin\theta \, d\theta. \tag{5.3}$$

When y varies from 0 to r, θ varies from $\frac{\pi}{2}$ to 0. If we permit θ to vary in the reverse direction, i.e., 0 to $\frac{\pi}{2}$, we may delete the minus sign.

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ETHNOLOGY.—*Interesting animal foods, medicines, and omens of the eastern Indians, with comparisons to ancient European practices.*[1] LLOYD G. K. CARR, Hendrix College, Conway, Ark. (Communicated by W. N. Fenton.)

At this time when attention is turned toward emergency foods and medicines, those little-known foods and medicines of the Indian such as insects, turtles, frogs, salamanders, fishing worms, and grubs may be considered. In time of great need one can make a fairly wholesome supplementary meal on these creatures, securing in turn a supply of minerals and possibly vitamins.

Turning to the reptile lore of the North[2] we note that the Montagnais really have so little to do with snakes that the only use to which they are put is as a cure for rheumatism, for which the skin of a snake is necessary. Dr. Speck tells us, "These people of the north do not fear snakes. They sometimes put them inside their shirts and carry them about."

From Speck we get further impressions of reptile lore among these northern Indians. It is found that northern Algonkian herpetology teaches that sympathetic influences are active through things and ideas and names. He says:

> Hence in the practice of therapeutics, a snake-skin, according to Penobscot belief, becomes a cure for rheumatism when bound around the infected part. Such a skin must have been taken from a living snake. The idea is no doubt derived from the feeling in the native mind, that a creature with so pliable a frame is not only free from stiffness himself, but that contact with him can cure stiffness in others. Similarly, a snake-skin, the Malechite say, worn around the head or hatband, will ward off enemies. A snake's tongue taken from a living snake, dried and carried about, will both cure and prevent a toothache. Further south the Mohegan and the Iroquois believe that a toothache can be cured by gently biting the body of a living Green snake.

Josselyn,[3] writing from voyages made in America, 1638 and 1663, speaks of the employment of reptiles and batrachians by the Massachusetts Indians. In speaking of the "tortous" (land turtle) he states, "They are good for the Ptisick, Consumption and some say the Morbus Gallicus (venereal disease)." Josselyn records that the "Green-turtle is the best for food, and that it is affirmed that the feeding upon this turtle for a twelvemonth forbearing all other kinds of food will cure absolutely Consumptions, and the Great Pox (syphilis); They are very delicate food, and their eggs are very wholesome and restorative."

Also "the ashes of a Sea-turtle mixed with oyl or Bearsgrease causeth hair to grow; the shell of a land-Turtle burnt and the ashes dissolved in wine and oyl healeth sore legs: the flesh burnt and the ashes with wine and oyl healeth sore legs: the ashes of the burnt shell and the whites of eggs com-

[1] The author expresses great appreciation for the association he was able to enjoy with the late Dr. Frank G. Speck, professor of anthropology at the University of Pennsylvania, under whose guidance this study was begun, and for a grant received through Hendrix College from the Carnegie Foundation for the Advancement of Teaching, which enabled the author to bring to a conclusion a preliminary report on the ethnozoological phase of his studies.

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pounded together healeth chaps in women's nipples and the head pulverized with it prevents the falling of hair, and will heal the Hemorrhoids, first washing of them with white wine, and then strewing on the powder."

With respect to the rattlesnake he orders this usage. "They have Leafs of Fat in their Bellies, which is excellent to anoint frozen Limbs, and for Aches and Bruises wondrous soveraign. Their Hearts, swallowed fresh, is a good Antidote against their Venome, and their Liver (the Gall taken out) bruised and applied to thier Bitings is a present remedy." Also their skins were said to be of value, "Their skins likewise worn as a garter is an excellent remedie against the cramp."

Gladys Tantaquidgeon,[4] in her study of the Delaware formerly of the Pennsylvania area, makes interesting comments with respect to the use of snake oil by the Delaware. "Rattlesnake oil is valuable in treating stiff joints. It is very powerful and should be used sparingly. Only a few drops on the finger tips, and applied to the affected parts. The skin may be bound on the wrists and ankles to strengthen them." Among the Wampanoag of Cape Cod, however it is believed that if the oil is used alone, "it will unjoint you." Likewise, the eastern Cherokee Indians have a snake oil remedy.

In the tradition of the Powhatan Tribes of Virginia some odd animal medicines and foods stand out. Mott Byrd, a Rappahannock Indian in his seventies, told that a snake shell ground up was highly prized as it causes boils to come to a head. Snakes play another important part in the medicines of the Rappahannock Indians. Speck[5] relates that the blacksnake skin wrong side out is worn as a belt around the waist to relieve backache or rheumatism. This is somewhat similar to the Massachusetts Indians use of the rattlesnake skin for cramps.

Turtles have been used by the Indian tribes of Virginia from early times. Gabriel Archer, writing in 1607, speaks of an Indian of the town of Arahatec on the James River below the falls, "He made ready a land turtle which he ate." Today the Pamunkey use the terrapin and turtle as incidental foods. The terrapins (*Chrysemys* spp.) are dredged in wintertime in mud bottoms of rivers and creeks with net and iron drag in 5–8 feet of water. The shells are cut apart and the flesh is made into soup. If eaten out of season it is said that they will cause eye swelling and a tickling in the throat as they go down. From the time of Josselyn the Virginia Indians have used their Indian word "Terrapin" for the designation of the turtle that occupies rivers, "The Turtle that lives in Lakes and is called in Virginia a Terrapin."

The snapping turtle (*Chelydra serpentina serpentina*) is taken by metal hooks baited with salt eel or catfish, tied to arrowwood (*Viburnum* sp.) stick, the bait being allowed to rest on the bottom. The use of cane stalks is employed by the Chickahominy. They are caught during January and may be cooked, boiled or roasted in their own shells as a "turtle shell dish."

The terrapin (*Terrapene carolina carolina*) called highland skillpot by the Virginia Indians is found in fields, woods or highlands, occasionally also by rivers from April through the fall months. It is rarely eaten, but sometimes it may be roasted; the legs only may be eaten or made into soup. The flesh is said to smell strongly.

Terrapin eggs (various species of *Chrysemys*) are considered a wholesome delicacy among the Pamunkey and are eaten as a part of a meal. Clutches of 10 to 20 eggs are found in sand banks along swamp and river edge, where signs betray recent laying. Hawks, eagles, crows, owls, skunks, and opossums know the time and place to hunt them, and one can often locate the eggs by observing the hunting habits of these creatures. They are gathered from the end of May through the summer months. They are boiled, the tough skin being peeled off.

Salamander eating is not absent in the incidental diet of the Cherokee. It is especially interesting to find that the "spring lizard" (probably *Gyrinophilus danielsi danielsi*), which inhabits the mountain streams, has been eaten by the Indians, as Jesse Lambert informs us. Also the water dog, or "hellbender" (*Cryptobranchus alleganiensis*), is utilized by the Cherokee for soups and stew.

[4] TANTAQUIDGEON, GLADYS. *A study of Delaware Indian medicine practice and folk beliefs*: 67. Pennsylvania Historical Commission, 1942.

[5] Loc. cit.

Turning to the Nanticoke reptile lore we find the belief that if hogs eat "ground puppies," the large *Ambystoma* salamanders, they will die. This is no doubt true, for toxic principles are present in the skin of the salamanders, as in the toads. Lincoln Harmon told that if one swallows a scorpion, which is the designation of the blue-tailed skink (*Eumeces fasciatus*) and also the fence lizard (*Sceloporus undulatus*) "in going down it will eat your heart, thereby killing you. Also death will ensue if they make a complete circle around your body."

Winona Wright advises that placing a blacksnake on the fence was sure to bring rain. She had observed this to have been true a number of times. Another interesting omen of the Indians, this time of the Massachusetts Indians, concerns the use of the Rattlesnake skin for cramps.

Insects are also an important part of the diet of the Indian. Speaking with Dr. Speck discloses that the Malechite Indians have a knowledge of eating ants. Sapiel Paul, over 60, born at French Village on the St. John River, New Brunswick, relates that his father took him to the woods continually on trapping, hunting, and woodcutting trips. Occasionally, when a dead tree was found swarming with black ants, he would crush some of the ants and give them to him to eat as a medicinally beneficial tidbit in the spring. Gabriel Polchis, another Malechite Indian, also indulged in this delicacy.

In connection with the medicinal properties of ants we learn some striking points. The *London Pharmacopaeia* of 1696 reveals, "Ants are hot and dry; excite lust, and by their sharp scent wonderfully refresh the spirit: the greater, or winged, with a little salt, cure the psora, or scab, and leprosie." Savarof, once addressing the Russian Soldiers, told them to "have a dread of the hospital! German Physic stinks from afar; is good for nothing and rather hurtful; but take care of your health; a soldier is inestimable! Your messmates will know where to find roots, herbs, and pismires (red ants) for your cure." Indeed, the ant is known to contain formic acid, which is used for medicinal purposes.

With respect to the Massachusetts Indians,[6] there is an interesting reference to lice-eating. During the time of John Eliot around 1646 a law was passed: "If any shall kill their lice between their teeth, they shall pay five shillings." It is obviously intimated that they were eaten, as they are very sweet and form, therefore, a tasty tidbit.

Among the Montauk Indians of Long Island the oak gall, produced by a wasp cynipid, is known as a food delicacy, the spongy inside fiber usually being eaten under the name "sour jugs." The sour nature of the fiber probably indicates vitamin-C content. Investigations along this line would be worth while.

Known to the Nanticoke Indians is the use of wasp nests, as well as cobwebs. Oscar Wright knows of their making use of the nests of the southern paper wasp (*Polistes annularis*). The papery pulp is allowed to soak in vinegar, in turn being applied to boils. Asbury Thompson relates that spider web will stop bleeding, while Oscar Wright mentions this story: "A man was very lazy and one day was chopping wood. He stuck his ax in the wood and went to sleep. In the meanwile the ax fell down, cutting his foot badly. It was thought that he was going to bleed to death, but spider web stopped the blood." Among the Delawares of Oklahoma also the spider web is applied to fresh wounds as a styptic.

Both Asbury Thompson and Oscar Wright speak of the employment of the bee sting for rheumatism. Indeed, the use of bee venom for this ailment has attracted much attention by the medical profession, some of whom hold it efficacious.[7] Dr. A. G. Richards writes me in this connection: "Bee venom was held in high repute during the Middle Ages and stressed by homeopathists in the 19th century. You will find it listed with directions for preparation in the 'American Homeopathic Pharmacopoeia' (under the name of 'Apium Virus'). There are persistent claims of use in the treatment of rheumatism both in the popular and medical literature. Also it has been used in skin

[6] DRAKE, SAMUEL G. *The book of Indians*: 113. 1841.

[7] BECK, B. F. *Bee venom, its nature and effects on arthritic and rheumatoid conditions*. New York, 1935.

diseases, inflammation of the bladder and uretha, etc."

From Mott Byrd comes information on the value of the bee sting. He described how as children they used to be friendly with bees. They would "lobolly with them" in the grass. In his early life they would stick five or six bees or wasps under a cloth, making them sting as a cure for stiff joints and rheumatism. He states that the bees "know enemy and clamp down." It would seem as though the bee sang, "Let me go." Mott's reply was, "Put it to us." He remarked that the stiff joints were already hurting so badly that one didn't really feel any pain from the sting. His ideas were that the bee carried away with it some of the poison in the stiff joints, "When the bee went down, the pain went down."

To the Rappahannock the thousandlegs (milliped) has been a worth-while item. It was found to be expert in cleaning out ears.

The 17-year locust (*Tibicen septendecim*) is a choice delicacy among the Cherokee. They dig them when they are just ready to emerge from the ground. For preparation, the legs are removed. Then the locusts are fried in hot fat, according to Jessie Lambert. Mrs. Moses Owl gives a method by which they are preserved. They are so highly prized that during years of abundance they are salted down and pickled for canning. Mrs. McClain knows of another method of preparation by the Cherokee; she states that they often concoct a locust pie from them.

From the extensive periodical on the *Cicada* by Marlatt[8] comes an early reference on the use of locust by the Indians:

> That the Cicada was eaten by the red men of America, both before and after the coming of the Colonists, is indicated in a memorandum, dated 1715, left by the Rev. Andreas Sandel, of Philadelphia, who, referring to the use of locusts as food in eastern Asia, states also that the Cicada is so used by the Indians. Dr. Asa Fitch corroborates this statement, giving as his authority Mr. W. S. Robertson, who informs him 'that the Indians make the different species of Cicada an article of diet, every year gathering quantities of them and preparing them for the table by roasting in a hot oven, stirring them until they are well browned'.

[8] MARLATT, C. L. *The periodical cicada*. U. S. Bur. Ent. Bull. **71**: 103–104. 1907.

Marlatt's remarks on its value are fitting here:

> Theoretically, the Cicada, collected at the proper time and suitably dressed and served, should be a rather attractive food. The larvae have lived solely on vegetable matter of the cleanest and most wholesome sort, and supposedly, therefore, would be much more palatable and suitable for food than the oyster with its scavenger habit of living in the muddy ooze of river bottoms, or many other animals which are highly prized and which have not half so clean a record as the periodical Cicada.

Among the insect clan, young wasps and yellow-jackets are eaten. These are found to be very sweet and luscious and should satisfy anyone's hunger for sweet, as they are readily available. When rambling around old barns in the country, one is certain to find wasp and yellow-jacket nests filled with the sweet white grubs, comprising a feast that is not forgotten. Hear what Vincent Holt[9] has to say about them in his admirable little book: "From bees, we derive a delicious sweet in the form of golden honey; from wasps we may, if we choose, derive an equally delicious savoury. What disciple of Old Izaak Walton, when he has been all the morning enticing the wily trout with luscious grubs baked to a turn has not suspected a new and appetising taste imparted to his mid-day of bread and cheese or a sandwich?" Again the Indian is far ahead of modern civilization in his knowledge and exploration of the value not only of insects, but also the other living things that comprise the organic environment. Close contact with it and keen observation has made the Indian the greatest interpreter of nature's secrets and patterns.

Also, by the Cherokee, Lottie Jenkins tells us, grubworms were formerly employed as food. She states that they can be made into a delicious thick soup. She told that her husband once sat down to a meal of grubworm soup, but he had no knowledge of what he was eating. He thought the soup very good until his Indian host advised him to "dig deep and get grubs." When he pulled up a fat grub, the thought of it was too

[9] HOLT, VINCENT. *Why not eat insects?* London, 1885.

much; he was unable to finish the meal. Another insect delicacy of the Cherokee is roasted cornworms.

It is only appropriate to relate here what Vincent Holt[10] has to say in general on insect-eating:

> Whilst confident that the caterpillars, the grubs, the chafers, and the butterflies will never condescend to eat us, I am equally sure that on finding out how good they are (and what excellent virtues they possess), we shall right away gladly determine to cook and eat them! Moreover, what a welcome change it will be to the labourer's meal of bread and bacon day after day for him to get a savoury mess of fried cockchafers, or of dainty grasshoppers done on toast! In these respects the birds are much more sensible than ourselves; they well know the value of the fat chafer as food. With that joy the jaunty rooks pounce upon its luscious grubs when they follow the plough with long strides over the upturned lea! What a feast the wise creatures obtain when aloft on the wing, by devouring the fledged beetles swarming in the tall tree tops!

Sally Gordon told that the daddy-longlegs if swallowed would break up chills and that lice had been swallowed for yellow jaundice. This is apparently a parallel to an English usage recorded in the London Dispensatory (1695), "They are eaten by rustics for the jaundice and consumption; put alive into the meatus they provoke urine; *Vivis in penis organum intimissis ad ciendam urinam.*"

Josselyn has several comments on frogs.[11] One alludes to the pond frog. "They are of a glistening brass colour, and very fat, which is excellent for Burns and Scaldings, to take out the Fire, and heal them, leaving no scar; and is also very good to take away any Inflammation." The other to the tree frog. "There is also many times found upon the leaves of the Oake a creature like a frog, being thin as a leaf, and transparent, as yellow as gold, the English call them Tree-Frogs or Tree-Toads . . . they are said to be venomous, but they may be safely used, being admirable to stop women's over-flowing courses hung about their necks in a Taffetie bag." Are we to suppose that this is pure fancy or "superstition"? Let us now stop at this point and explore deeper into the significance of what might be listed as heathen practice. Indeed the skin glands of the batrachians are known to contain toxic compounds of medicinal value and oddly enough some of the substances from these glands are known to possess astringent and hemostatic properties. A word from a leading authority on the chemistry and properties of these substances is pertinent:[12]

> That there is present in the toad an active, poisonous principle has been recognized since antiquity, and although the nature of the poison was endowed with various legendary beliefs throughout the middle ages, it has long been recognized that the venom of the toad has definite medicinal qualities. For centuries the Chinese have employed as a drug a dried preparation from a common toad. The remedy is known as Ch'an Su in China and as Senso in Japan. Ch'an Su is sold in the form of hard, dark brown cakes which were applied externally in the treatment of toothache, sinusitis, and hemorrhages of the gums. Dried and powdered toad skins were commonly used as a remedy for dropsy until Withering introduced the use of the foxglove drug. It has been known for nearly a century that the poison of the toad has a specific, digitalis-like action on the heart, the intravenous injection of very small doses in frogs promptly inducing a systolic standstill.

With respect to the drawing or astringent effect which would be of value on burns, and also to the bleeding-stopping effect, we have this note: "It is interesting that the Chinese drug Ch'an Su has been found to contain, in addition to the cardiotonic agents, this pressor substance of recognized astringent and hemostatic properties."

To this day the value of the frog as a medicinal agent is apparent to the Cherokee of western North Carolina. Consider the information contributed by Moses Owl. He reveals that the "toad frog is good for goiter. The live toad is held against the chest until you sweat." A jellow juice is thereby produced which is supposed to relieve the goiter.

The Cherokee also eat the pond frogs, using them for soup after they are suitably dressed. Jesse Lambert relates that frog soup has been administered for whooping cough—"one half glass every day before breakfast until cough ceases." Moses Partridge, an

[10] Ibid.
[11] Op. cit.
[12] FIESNER, L. F. *Chemistry of natural products related to phenanthrene*. Monogr. Ser. No. 70: 302–303. 1936.

older member of the Cherokee group, has used this remedy effectively.

In connection with whooping cough, polecat (skunk) grease has been found effective. Nicker Jack George advises that one take a few drops internally. It is thought to cure a rattle cough.

Dropping into the southeastern area brings to view a number of food and medicinal oddities of an animal nature. In working here among the Indians, numerous notable items have emerged. Lincoln Harmon, a Nanticoke Indian of Indian River, Del., tells of the use of salt herring applied to arms, hands, or feet for fever. He states that he has known people to "get rid" of colds or grippe. The procedure is to go to a neighbor, in the language of Lincoln Harmon, to "get bait on. Put on hands or any part of body. One sits near a fire. Fish is considerably dried or parched when you take it off. Better not let one application be all, better put new ones on as fish dry up."

One is intrigued to find that similar usage was employed in Queen Elizabeth's time in England. The *Rich storehouse* (1596) contains this information, "For the swelling of the legs that comes on by cold or otherwise, take white herrings out of their pickle, and open them, and then lay the insides of the same herrings to the soles of your feet when you go to bed, and so let them remain all night; in the morning apply new ones again. Use this five or six times and the same will help you, *probatum est*." For ague also it includes, "Take a herring that is well pickled, and split it on the belly side, and warm the same very hot, and lay it to both soles of the feet of the party grieved, and this will help immediately." This makes one wonder whether this is an Indian or an English practice. It may have been discovered independently by both groups or the Nanticoke may have learned it from early contact with the English.

Among the Nanticoke again, but this time from Asbury Thompson, an old herbalist of the group, the use of fish eyes is mentioned. He tells that fish eyes are good for bowel movements. "Take as pills, the cheapest kind," is his advice.

Asbury Thompson also told of a well-known remedy for rheumatism which is employed by the Nanticoke Indians. He advises, "Put fishingworms in bottle, let die, apply oil for stiff joints and rheumatism. Smells bad, but sure helps stiff joints." The Cherokee Indians of western North Carolina appreciate also the virtue of the earthworm. They take the flesh of "redworms" and apply to the body to draw out thorns. It is worth noting that biochemists[13] have given attention to the lipids (fats) of the earthworm, discovering fatty acids that enter into therapeutics. Furthermore, a bronchial (lung) dilating principle has been isolated.[14] So here again the Indians have made discoveries anciently known to them in their medical lore, but known only recently to the medical world at large.

Living in the shadows of the Great Smoky Mountains of North Carolina, the Cherokees have a high regard for the singular animal foods and animal medicines such as fishing worms, locusts, grubs, and salamanders. Mrs. Moses Owl has seen the red worm (eath worm) poultice employed in drawing out a thorn. "Just make your poultice of chopped up worms. Draws so powerfully, have to take off soon." According to Lottie Jenkins, the red worms have been used in making soups. She states that they are really not bad and form a gelatinous soup that is quite palatable and healthful. So in the economy of the Cherokee the earthworm is valuable both as a medicine and as food.

Another food item which is valuable to the Pamunkey is the mussel. Mussels are gathered from March to February in shoal water along shores of rivers, where, in a rising tide in about ten inches of water, they lie open. They are stewed or boiled or eaten raw; not gathered to last over or be preserved. Another mollusk utilized by the Pamunkey is the Kahonk (Conch), found only in the York River, 12 miles east of the present reservation, from West Point to the bay. They are found in low water, by feeling with the bare feet on sand below the low-tide line. They are roasted by being put on sticks of fire. They are never dried or smoked for preservation.

[13] LOVERN, JOHN A. Biochem. Journ. **34**: 709–711. 1940.

[14] CHOU, T. G., CHAND, C. C., and CHU, H. P. Chinese Journ. Physiol. **12**: 147–153. 1937.

A curious weather attribute is given to the "fever-ague" worm (woolly-bear) by the Nanticoke. By reading the color pattern one can predict the severity of the weather. The months represented in succession from head to tail of the worm are December, January, and February. Elwood Wright tells if there is much black on the head, cold weather is meant, if short black more moderate; of much tan, open month is signified. If it appears black on the head end, brown on other, December will be rough, January and February open. If reversed, December will be open, while January and February will be rough. If totally colored, he explained, "It hasn't fully got its stripes yet."

One wonders whether this is native to the Indian, for I have obtained from the English settlers in the Blue Ridge of Augusta County, Va., a knowledge of the "feeble worm" as they call it, foretelling the weather. Mrs. Jack Kelly, of Stuarts Draft Community, has observed that if the feeble worm is black on either end a cold winter will follow, but if black in the middle, a mild or in-between season will invariably occur. The Nanticoke, who, as their name implies, were great fishermen, called the spring peepers (*Hyla crucifer*) herring frogs because they would always announce the "running" of the herring in the spring.

ICHTHYOLOGY.—*A new anchovy of the genus* Anchoviella *from the Poti and Parnaiba Rivers of Brazil.* LEONARD P. SCHULTZ and RUI SIMÕES DE MENEZES.

Since Hildebrand (Bull. Bingham Oceanogr. Coll. **3** (art. 2): 1–165, figs. 1–72, 1943) published "A Review of the American Anchovies (Family Engraulidae)" four other papers have appeared or were not included in Hildebrand's revision that deal with South American Anchovies. These are: Fowler, Proc. Acad. Nat. Sci. Philadelphia **93:** 124, fig. 2, 1941; *ibid.* **95:** 311, fig. 1, 1943; Hildebrand and Carvalho, Copeia, 1948, no. 4: 285–296, figs. 1–4; and Schultz, Proc. U.S. Nat. Mus. **99:** 37–54, figs. 4–8, 1949. After comparing the specimens of anchovies which form the basis of this contribution with the species described in the above papers and with related material in the U.S. National Museum collections, we have concluded that our specimens represent an unnamed species.

Anchoviella potiana, n. sp.

Fig. 1

Holotype.—U.S.N.M. no. 112081, from Poti and Parnaiba Rivers, Teresina, State of Piaui, Brazil, collected in September 1949 by Rui Simões de Menezes, standard length 113.7 mm, total length 136.5 mm.

Paratypes.—U.S.N.M. no. 112082, collected along with the holotype and bearing same data, 7 specimens, 107 to 118 mm in standard length. Also 8 specimens in collection of Servico de Piscicultura, Fortaleza, Ceará, Brazil.

Description.—Detailed measurements were made on the holotype and 15 of the paratypes and these data are expressed in thousandths of the standard length in Table 1. Counts for the new species are recorded in Table 2.

Body compressed, deep, greatest depth at about dorsal origin, 3.1 to 3.4, and head 3.6 to 3.7, both in standard length; head shorter than greatest depth of body; snout bluntly pointed, projecting about ⅓ its length beyond tip of mandible, about ⅔ eye, only a little longer than pupil; eye about 4.0 to 4.2 in head; maxillary ending posteriorly in a truncate to a broadly rounded tip that reaches to but not past joint of mandible, contained about 1.3 to 1.4 in head; mandible pointed, slightly curved dorsally at tip, reaching a vertical line a little behind rear edge of posterior nasal margin; teeth minute, very numerous, along edges of both jaws, cheek 7.0 to 8.2 and postorbital length of head 5.5 to 5.8 in standard length; angle of cheek varies from 35° to 44°; gill rakers long, slender, the longest about 3 times in postorbital length of head, each gill raker on the first four arches with two rows of numerous minute spinules on the inner or posterior side; no gill rakers on the posterior side of the first three arches, but short rakers occur on posterior side of fourth gill arch; depressed length of dorsal fin 1.4 to 1.5 in head; the first branched rays of dorsal fin reaching to opposite or not quite to tip of last dorsal ray when fin is depressed; distal margin of dorsal slightly concave when

TABLE 1.—MEASUREMENTS MADE ON SPECIMENS OF ANCHOVIELLA POTIANA, N. SP., RECORDED IN THOUSANDTHS OF STANDARD LENGTH

Measurements	Measurements by Schultz[1]							Measurements by Menezes[1]							
	Holotype	Paratypes						Paratypes							
Standard length in millimeters	113.7	113	107	111	109	111.4	118	103	112	115	104	109	104	109	109
Greatest depth	321	315	302	313	323	303	316	320	303	296	308	312	308	321	321
Length of head	282	286	278	270	278	278	263	252	259	252	250	248	260	239	239
Postorbital length of head	175	186	171	173	179	170	178	145	161	156	154	147	163	147	147
Snout	46	44	51	43	44	45	47	58	45	43	48	55	58	46	46
Eye	73	65	70	75	72	73	69	68	62	61	67	64	67	73	64
Length of mandible	187	192	192	186	189	186	191	155	152	156	144	156	173	156	165
Longest gill raker	64	63	69	59	62	60	64								
Interorbital (bony) space	67	59	65	62	62	65	58	78	80	78	77	73	77	73	73
Tip of snout to: Rear edge of maxillary	219	217	221	203	211	209	210	214	205	213	221	206	221	211	211
Dorsal origin	519	514	500	504	517	516	508	534	518	513	519	514	519	541	514
Anal origin	627	638	650	624	657	605	624	640	625	617	673	624	654	642	642
Length of anal fin base	282	269	280	266	279	269	267	281	285	278	288	275	288	284	284
Length of dorsal fin base	121	127	118	122	127	135	131	136	125	139	135	138	144	128	138
Length of pectoral fin	180	165	171	173	185	168	176	175	179	178	173	183	173	183	183
Length of pelvic fin	102	99	106	106	114	97	105	97	107	104	111	101	111	106	106
Length of pectoral axillary scale	104	89	106	110	84	114	93	97	98	96	106	101	96	83	101
Least depth of caudal peduncle	123	124	125	117	125	124	119	116	125	113	115	119	125	119	119

[1] Differences between the two sets of figures such as head length, postorbital length of head, length of mandible, interorbital space, and length of dorsal fin base are probably caused by different methods of measuring.

TABLE 2.—COUNTS RECORDED FOR ANCHOVIELLA POTIANA, N. SP.

Number of fin rays

Dorsal			Anal					Pectoral			Pelvic			Branched caudal	
														Dorsal lobe	Ventral lobe
iii	10	11	iii	22	23	24	25	i	11	12	i	5	6	9	8
16	7	9	16	2	8	5	1	16	4	12	23	2	21	15	15

Number of scales

Vertical rows from gill opening to caudal base			Dorsal origin to mid-ventral line	
41	42	43	8	9
10	5	1	10	5

Number of gill rakers on first arch

Above angle						Below angle										
47	48	49	50	51	52	51	52	53	54	55	56	57	58	59	60	61
2	3	2	2	4	3	1	—	1	1	3	2	3	4	—	—	1

distended; caudal fin deeply forked; distal margin of anal fin concave anteriorly, first anal rays longest; first dorsal ray of pectoral fin longest; tips of pectoral fins reaching to or not quite to insertion of pelvics; pelvic fins reaching about ½ to ⅔ the way to the anal origin; dorsal fin origin about equidistant between tip of snout and base of caudal fin; origin of anal fin about under base of last or next to last dorsal ray; axillary scale of pectoral fin extending one-half to two-thirds the way along length of pectoral fin; intestine with one main loop.

Color in alcohol.—Straw-colored in alcohol dorsally, sides and belly silvery; dorsal side and tip of snout with black pigment, predorsal area of back with dark pigment intensified just behind occiput to form a blotch and then another just in front of dorsal origin; rear margin of caudal fin dusky; upper sides and back with some dusky pigmentation.

Remarks.—This new species is chiefly characterized by its numerous gill rakers on both limbs of the arches in conjunction with other characters which make it referable to the genus *Anchoviella*, such as lack of gill membranes across isthmus, presence of very numerous minute teeth on edges of both jaws; origin of anal behind that of dorsal fin; long, slender, numerous gill rakers on both limbs of gill arches; vertebrae about 41; one main loop of intestine; anal origin under rear of base of dorsal fin; maxillary broadly rounded or truncate posteriorly and not reaching past joint of mandible; dorsal origin about equidistant between tip of snout and base of caudal fin.

The occurrence of 47 to 52 + 51 to 61 gill rakers on the first gill arch of any species referable to the genus *Anchoviella* might cause one to cast doubt on our generic allocation, but comparing this new species with various members referred to the other genera of American anchovies leaves no doubt in our mind that *potiana* is an *Anchoviella*. The details of the gill rakers, long, slender, with the two rows of fine spines on inner edge, and shape of maxillary among other characters remove it from the genus *Anchovia*, which also has species with very numerous gill rakers, but a posteriorly pointed maxillary.

A. potiana would run down through Hildebrand's key to the species of *Anchoviella* on pp. 109–111 closest to *A. pallida* but does not agree with that species because *pallida* has 28 to 34 + 36 to 45 gill rakers and *potiana* has 47 to 52 + 51 to 61 on first gill arch. Fowler (1941, *l.c.*) described *Anchoviella iheringi* from the Rio Jaguaribe, Brazil, and this was not included in Hildebrand's revision but it has only 14 + 19 gill rakers, far too few to be close to *potiana*. Hildebrand and Carvalho (1948, *l.c.*) described two new species of *Anchoviella* from Brazil, *A. victorae* and *A. nitida*, with 21 to 23 + 29 to 33 and 18 to 20 + 23 or 24, respectively, on first gill arch of both species. Thus *victorae* and *nitida* are not close to *potiana*. We have not noticed any other species of *Anchoviella* in the literature.

Named *potiana* after the Poti River of Brazil.

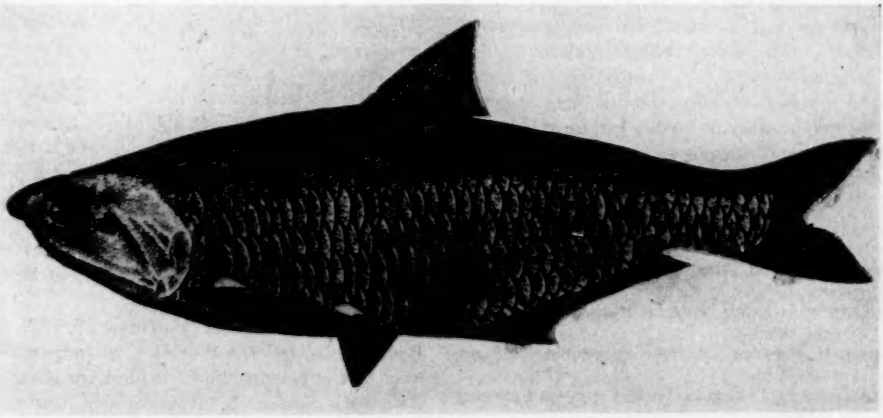

FIG. 1.—Drawing of one of the paratypes of *Anchoviella potiana*, new species, by Mario Dias-Maia, Servico de Piscicultura, Fortaleza, Ceará, Brazil.

PROCEEDINGS OF THE ACADEMY

53D ANNUAL MEETING

The 53d Annual Meeting, concurrently with the 376th monthly meeting of the Academy, was held as a dinner meeting in the Ballroom of the Kennedy-Warren on the evening of January 18, 1951. President F. B. SILSBEE presided.

After the dinner, Dr. Silsbee called the meeting to order. The minutes of the 52d Annual Meeting were approved as published in the Journal **40:** 198–205. 1950.

The following reports by the various officers, committee chairmen, auditors, and tellers were read and approved:

REPORT OF THE SECRETARY

During the Academy year—January 29, 1950, to January 18, 1951—125 persons were elected to regular membership, including 114 to resident and 11 to nonresident (56 were elected last year). Of these, 84 resident and 7 nonresident qualified for membership. Ten resident members elected to membership in the preceding Academy year qualified during the present Academy year just ended. The new members were distributed among the various sciences as follows: 24 in physics, 21 in chemistry, 12 in entomology, 7 in zoology, 5 in mathematics, 4 in engineering, 2 each in bacteriology, geophysics, biochemistry, and mammalogy, and 1 each in paleontology, electrical engineering, geology, anthropology, mineralogy, botany, medicine, geodesy, mechanical engineering, and astronomy.

Nine resident members and one nonresident member, having retired from the gainful practice of their professions, were placed on the retired list of members to enjoy the privileges of active membership without further payment of dues. Eight resident members and one nonresident member resigned in good standing.

The deaths of the following members were reported to the Secretary:

GEORGE S. RICE, Alexandria, Va., on January 3, 1950.
CLARENCE A. REED, Takoma Park, Md., on January 14, 1950.
HENRI F. PITTIER, Caracas, Venezuela, on January 27, 1950.
CARLOS DE LA TORRE, Habana, Cuba, on February 19, 1950.
OAKES AMES, Cambridge, Mass., on April 28, 1950.
L. O. HOWARD, Washington, D. C., on May 1, 1950.
HOWARD S. REED, Berkeley, Calif., on May 12, 1950.
HERBERT S. BARBER, Washington, D. C., on June 1, 1950.
EDWARD A. BIRGE, Madison, Wis., on June 9, 1950.
FRANK W. SCHWAB, Washington, D. C., on June 18, 1950.
M. A. RAINES, Washington, D. C., on July 1, 1950.
C. W. WARBURTON, Washington, D. C., on September 22, 1950.
CHESTER STOCK, Pasadena, Calif., on December 6, 1950.
JOHN F. EMBREE, New Haven, Conn., on December 22, 1950.
H. E. EWING, Takoma Park, Md., on January 5, 1951.

HENRI F. PITTIER, CARLOS DE LA TORRE, and L. O. HOWARD were honorary members.

On January 18, 1951, the status of membership was as follows:

	Regular	*Retired*	*Honorary*	*Patron*	*Total*
Resident	573	57	0	0	630
Nonresident	173	34	10	0	217
Total	746	91	10	0	847

The net changes in membership during the past year are as follows:

	Regular	*Retired*	*Honorary*	*Patron*	*Total*
Resident	+58	+7	−1	0	+64
Nonresident	+14	+1	−2	0	+13
Total	+72	+8	−3	0	+77

During the Academy year 1950 the Board of Managers held 9 meetings, with an average attendance of 18 persons. The following important matters were considered:

At the 435th meeting, held on February 20, 1950, the Board approved the sale of 818 shares of Washington Sanitary Improvement Co. stock. [On June 20, 1950, the stock was sold at a price considerably higher than what the Academy paid for it many years ago.]

The Academy was represented at the Seventh International Botanical Congress, held at Stockholm, Sweden, July 12–20, 1950.

At the 439th meeting, September 25, 1950, the Board instructed the Secretary to prepare and mail to the membership a request for changing Article II, Section I, of the bylaws, increasing the number of active members from 750 to 1,000, and resident membership from 600 to 800. In

all, 389 ballots were returned, of which 374 voted in favor of the amendment, 11 opposed, 3 were unsigned, and 1 did not vote. The need for this increase in membership was due to a large extent to the very active Committee on Membership, as indicated by the election of 125 scientists to regular membership.

During the Academy year, eight meetings of the Academy were held, as follows:

On February 16, 1950, FRANK H. H. ROBERTS, JR., Bureau of American Ethnology, delivered his retiring presidential address on *Archeology and the modern world.*

On March 16, 1950, the 1949 Academy Awards were presented to EDWARD G. HAMPP, National Institutes of Health, for work in the biological sciences; RICHARD K. COOK, National Bureau of Standards, for work in the engineering sciences; and to JOHN A. HIPPLE, National Bureau of Standards, for work in the physical sciences. The Academy awarded Certificates of Merit to six outstanding local high-school science students: MILES DAVIS, Central High School; WILLIAM EDWARD DRISSEL, Gonzago High School; PHIL STRATFORD WORK, Western High School; PATRICIA MORSE FEDERICO, Woodrow Wilson High School; DONALD JASON BYERS, Woodrow Wilson High School; and PAUL DOUGLAS SHEATS, Woodrow Wilson High School.

On April 20, 1950, THOMAS WALLER GEORGE, Naval Research Laboratory, addressed the Academy on *Dynamical aspects of plastic flowing in solids.*

On May 18, 1950, FRANK M. SETZLER, U. S. National Museum, addressed a joint meeting of the Academy and the Anthropological Society of Washington on *Aboriginal Australia.*

On October 19, 1950, CHARLES ARMSTRONG, National Institutes of Health, addressed the Academy on *Poliomyelitis: Its occurrence and behavior in our population.*

On November 30, 1950 JAMES A. VAN ALLEN, Johns Hopkins University Applied Physics Laboratory, addressed the Academy on *New Experiments in the upper atmosphere.*

On January 18, 1951, PER K. FROLICH, Merck & Co., gave an after-dinner talk to the Academy on *Medicinal chemicals.*

Six of the meetings were held in the Cosmos Club. The joint meeting with the Anthropological Society of Washington was held in the auditorium of the U. S. National Museum. The meeting on January 18, 1951, was held at the Kennedy-Warren.

The Academy sponsored the annual Science Fair for high school students and the weekly issue of the Science Calendar in the local newspapers.

FRANK M. SETZLER.

REPORT OF THE TREASURER

The Treasurer submits the following report concerning the finances of the Washington Academy of Sciences for the year ended December 31, 1950:

RECEIPTS

Dues, 1949	$73.00	
1950	3,788.00	
1951	124.00	$3,985.00
Journal, Subscriptions,		
1946	6.00	
1947	7.50	
1948	7.50	
1949	21.75	
1950	611.24	
1951	680.45	
1952	5.06	1,339.50
Reprints,		
1949	201.57	
1950	568.53	770.10
Sales,		
1950		93.43
Interest and dividends		1,521.50
Directory (33d ed.)		6.00
Monograph no. 1		189.67
Transferred from invested funds		1,000.00
Transferred from Savings Account		25,000.00
Annual dinner (1950)		294.00
Refund, service charge, A. S. & T. Co.		7.43
Sale Washington Sanitary Improvement Co. Stock		26,114.65
Total receipts, 1950		$60,321.28
Cash balance, January 1, 1950		1,635.53
		$61,956.81

DISBURSEMENTS

	1949	*1950*	*Total*
Secretary's Office	$110.87	$370.39	$481.26
Treasurer's Office		304.59	304.59
Subscription Manager & Custodian of Publications	8.95	21.72	30.67
Meetings Committee	35.50	208.80	244.30

Membership Committee	1.00	.50	1.50
Journal			
Printing & mailing	613.28	4,887.38	5,500.66
Illustrations	68.76	521.91	590.67
Reprints	246.66	673.16	919.82
Office			
Editorial Asst.	25.00	275.00	300.00
Miscellaneous	1.58	42.83	44.41
	$1,111.60		
Annual Dinner (1950)			
Tickets and programs		25.00	
Refunds		10.50	
Hotel 2400		274.20	
Projection Service		18.50	328.20
Monograph no. 1			
Postage, wrapping, etc.		3.08	3.08
40-year Index		1,000.00	1,000.00
Science Fair		100.00	100.00
Science Calendar		10.00	10.00
Fireproof records cabinet		263.00	
and material for base		1.66	264.66
George Banta Publishing Co.			
Cartage on overcopies		69.93	69.93
Deposited in Savings Account		26,114.65	26,114.65
Stock			
Massachusetts Investors Trust, 400 shares @ $33.62		13,448.00	
Investment Co. of America, 400 shares @ $11.61		4,644.00	
State Street Investment Corporation, 100 shares @ $61.25		6,125.00	24,217.00
Debit memos:			
1378 A $0.89 (exchange)			
1388 A 7.43 (service charge)			
1423 A 0.56 (exchange)		8.88	8.88
Total disbursements		$59,422.68	60,534.28
Cash book balance as of December 31, 1950			1,422.53
Total			$61,956.81

RECONCILIATION OF BANK BALANCE

Balance as per cash book, Dec. 31, 1950			$1,422.53
Balance as per Amer. Sec. & Trust Co. Statement of Dec. 18, 1950		$1,373.36	
Receipts undeposited		1,227.18	
Total		$2,600.54	
Checks outstanding, as of Dec. 31, 1950			
No. 1018	$5.41		
1263	5.00		
1429	1,144.02		
1430	23.58	1,178.01	$1,422.53

INVESTMENTS

Potomac Electric Power Co.			
Certificate No. TAO 1977—40 shares 3.6% pref. at $50			$2,000.00
City of New York—3% (Transit Unification)			
Due—June 1, 1980			
Certificate No.			
D 20186	$500.00		
C 71038	100.00		
C 71039	100.00		
C 71040	100.00		$800.00
First Federal Savings & Loan Assn.			
Investment account book			$1,000.00
Northwestern Fed. Savings & Loan Assn.			
Certificate No. 1380	$4,500.00		
1441	500.00		$5,000.00
United States Government			
Series G Bonds—			
No. M 332990 G	1,000.00		
M 332991 G	1,000.00		
M 332992 G	1,000.00		
M 332993 G	1,000.00		
M 1808741 G	1,000.00		
M 2226088 G	1,000.00		
M 2982748 G	1,000.00		
M 4126041 G	1,000.00		
M 5141346 G	1,000.00		
M 5141347 G	1,000.00		$10,000.00
Massachusetts Investors Trust			
400 shares at $33.62			$13,448.00
Investment Co. of America			
400 shares at $11.61			$4,644.00
State Street Investment Corp.			
100 shares at $61.25			$6,125.00
American Security & Trust Co.			
Savings Account			$1,161.52
Total			$44,178.52
Cash balance 12/31/50			1,422.53
Total			$45,601.05
Total as of Dec. 31, 1949		$29,662.40	
Total as of Dec. 31, 1950		45,601.05	
Increase		$15,938.65	

At the close of business on December 31, 1950, there were 52 members of the Academy in arrears, 34 for 1 year, 8 for 2 years, 2 for 3 years, 7 for 4 years, and 1 for 5 years.

HOWARD S. RAPPLEYE.

REPORT OF AUDITING COMMITTEE

The accounts of the Treasurer of the Washington Academy of Sciences for the year 1950 were

examined by your auditing committee on January 10, 1951.

A copy of the Treasurer's report was checked and found to be in agreement with the records. All disbursements had been previously authorized and are supported by vouchers or cancelled checks.

The securities of the society were inspected on January 11, 1951, and found to be in agreement with the list given in the report and to have all coupons attached that are not yet due.

The work of the committee was greatly simplified and lessened by the excellent manner in which the records have been kept and by the systematic and orderly arrangement of the books and of the report. Your Treasurer deserves the commendation of the Society for another year of service to the Academy.

(One member of the auditing committee, DR. C. L. GAZIN, was unable to assist in the audit because of his absence from the ciy.)

RAYMOND L. SANFORD.
WALTER D. SUTCLIFFE, *Chairman*

REPORT OF THE BOARD OF EDITORS

Volume 40 of the JOURNAL, for the year 1950, contained 424 printed pages, 4 less than volume 39 for 1949, despite which the cost of issuing the JOURNAL has again increased. The higher costs in 1950 are caused by the inflationary spiral of prices which began in July with the start of the war in Korea. The increases reflect the higher prices of paper and materials for which the contract specifies a cost plus basis. Reluctantly, the printer, Waverly Press, Inc., has requested permission to increase by ten per cent the rates on items specified by price in the contract, the increase to go into effect in January 1951; it is made necessary by higher wages and other cost increases. Waverly Press is to be commended for the equitable treatment it has given the JOURNAL in this matter.

During 1950 the JOURNAL published 81 submitted papers and 12 obituaries, together with proceedings of the ACADEMY and of two affiliated societies. The submitted papers comprized 66 in biological sciences, 6 in mathematics and the physical sciences, and 9 in other sciences. In addition to these, there were 16 abstracts of papers in the Proceedings of the Philosophical Society of which 10 were in physics, 2 in astrophysics, 1 in biophysics, 1 in medicine, 1 in mathematics, and 1 in fuel research.

The disbursements for the JOURNAL during 1950 were:

Printing, mailing, engraving, etc.	6,011.95
Reprints	822.00
Office—Editorial assistant	300.00
Office—Miscellaneous	30.79
Total	7,164.74
Charges to authors	954.73
Ne cost of the JOURNAL to Academy	6,210.01

In 1949 the net cost to the Academy was $6,013.84, $196.17 less than for the current year.

The Board of Editors wishes to acknowledge the cooperation of the Board of Managers and the officers of the Academy. Special thanks are due to MR. PAUL H. OEHSER who efficiently handles all matters pertaining to the technical side of printing and make-up of the JOURNAL. The Editors also wish to thank MR. FRANCIS C. HARWOOD, of Waverly Press, for his helpful suggestions.

FRANK C. KRACEK.
FREDERICK J. HERMANN.
WILLIAM F. FOSHAG.

REPORT OF CUSTODIAN AND SUBSCRIPTION MANAGER OF PUBLICATIONS

Subscriptions

Nonmember subscriptions in the United States and possessions	145
Nonmember subscriptions in foreign countries	82
Total	227

This represents a gain of 4 subscriptions over last year's total.

Inventory of stock as of December 31, 1950

Reserve sets of the Journal	
Complete sets, vols. 1–40	4 sets
Volumes 11–40	6 sets
16–40	9 sets
21–40	5 sets
Total sets more or less complete	25 sets
Back numbers of the Journal	
Numbers held in complete sets (4)	2,652
Numbers held in reserve for complete sets	8,263
Numbers held for sale separately	*
Total numbers on hand	*

* A count of these separate numbers has not been made recently, pending a rearrangement of the back stock and a subsequent recount and audit.

Proceedings
Complete sets, volumes 1–13 (1899–1911) 48 sets
(The copies of the separate articles that appeared in the Proceedings have not been counted.)
Monograph no. 1

Original issue	1,010
Copies sold or otherwise distributed	141
Number of copies on hand	869

Sales

During the year 1950, sales of the JOURNAL and PROCEEDINGS fell well below the sales recorded in 1949. No complete sets of the PROCEEDINGS were sold, and only 115 numbers of the JOURNAL were sold either separately, or as volumes.

Seven numbers of the PROCEEDINGS and three copies of the 1947–48 Directories were sold.

The sales of the Monograph fell off from those the previous year. This year 47 copies were sold. It was not possible to circularize prospective buyers during 1950 but it is expected to do this early in 1951. This it is hoped will increase the sales of the Monograph.

A gift of an almost complete set of the JOURNAL from the estate of the late Joseph A. Cushman and numerous other very welcome gifts of early numbers of the JOURNAL, have given us a good start toward making up another complete set. It is hoped that the older members who are considering the distribution of their library will remember the needs of the Academy in this respect.

The income from sales of copies of the JOURNAL, Proceedings, and Directory was $93.43, while sales of the Monograph yielded $189.67. This is a total income of $283.10.

Expenditures

Supplies	$6.50
Stamped Envelopes	.91
Postage expended in connection with the JOURNAL, etc.	6.60
Postage expended in connection with the Monograph	5.53
Total	$19.54

Storage

In last year's annual report it was mentioned that a rearrangement of the storage facilities that we have in the Smithsonian Institution Building was in progress. It was impossible to finish this in the limited free time at the disposal of the custodian, but it is expected that this work will be finished during 1951. At that time it will be possible to have a count made of the stock on hand.

HARALD A. REHDER.

REPORT OF THE ARCHIVIST

During the year the present incumbent with the active cooperation of his predecessor worked over all Academy materials heretofore turned in for deposit in the Academy's Archives. Much material of an ephemeral nature has been discarded and the remainder reorganized and rearranged so that it is hoped that the files will be readily usable hereafter. An itemized inventory of the materials in hand follows:

Scrapbook containing miscellaneous printed matter of the Academy, including notices of meetings, 1898–1922, inclusive.
Folder containing similar material since 1922. Very far from complete. Presumably a complete collection from 1923 to date is in Secretary's possession.
Red Books: Vol. 1 (1892, 1895, 1897, 1898, 1900). Unbound 1899, 1901, 1903, 1905, 1907, 1909. Vol. 2 (1911–1919) Red Books only, Nos. 18–22. Vol. 3 (1921–1935) Red Books Nos. 23–29 with Academy lists 1914, 1916, 1918, 1920, 1922, 1926. Unbound 1937, 1939, 1941, 1947–8 with Academy lists 1916, 1918, 1920, 1922, 1924, 1926.
Membership records, 1898–1948. Includes all pertinent records available on all members, including applications, acceptances, resignations, declinations, etc.
The Benjamin Franklin Medal presented to the Academy by the American Philosophical Society, commemorating 200th anniversary of his birth.
Original ballots with tally sheets, covering selection of charter members of the Academy, 1898. In wrapped package.
Personal data (names, addresses, degrees, etc.) of Academy members, 1901. In wrapped package.
Recording Secretary's minute book from January 1908 (48th meeting) to January 1936, inclusive (268th meeting) (10th–38th Annual meetings). *Bound.*
Minutes of the meetings of the Board of Managers, January 31, 1911–December 19, 1929, inclusive (165th–301st meetings). *Bound.*
Same. January 29, 1930–December 16, 1938 (302nd–349th meetings). *Bound.*
Same. February 10, 1939–October 18, 1943 (350th–385th meetings). *Bound.*
Same. 1st, 193, 287–399, in folder (unbound).
Treasurer's books:
Membership dues, 1898–1907, alphabetically by names.
Treasurer's cash books (receipts and disbursements).

(1) Feb. 1898–Dec. 1909.
(2) Jan. 1910–Dec. 1915.
(3) Jan. 1916–Dec. 1935.
(4) Jan. 1916–Dec. 1918 (receipts only)
(5) Jan. 1919–Dec. 1921 " "
(6) Jan. 1922–June 1925 " "
(7) June 1925–Sept. 1933 " "
(8) Oct. 1933–Dec. 1936 " "
(9) Ledger 1917–1928
(10) "Cash book" 1915–1927. A mess:
(11) " " 1928–1934

Letterpress books (nos. 2–7) Nov. 1, 1900–Jan. 17, 1922.
Volume 1 is missing.

Journal Washington Academy of Sciences
Volumes 1–30. Bound 1912–1940. 31–38. Unbound 1941–1948, 1949, 1950.

Proceedings Washington Academy of Sciences
Volumes 1–13 (1899–1911). *Bound.*

Proceedings The McGee Memorial Meeting. Washington Academy of Sciences, Dec. 5, 1913. 1916. (2 copies) *Unbound.*

Lectures on heredity. Reprints from Journal Washington Academy of Sciences, Bound in boards. 1917.

Lectures on scientific and engineering aspects of the war. Reprints from Journal Washington Academy of Sciences. Bound in boards. 1918.

Photographs, Past-Presidents, Washington Academy of Sciences.

Halftone cuts used for portrait illustrations in Red Book, 1947–48 (4 boxes).

Original photographs as above, mounted on large cards (one large package).

Facsimile copy of the charterbook and signatures in the first journal book of the Royal Society of England. 1912. Folio. Presented to the Academy by the Royal Society.

Reports of officers: Archivist, Auditors, Custodian of Publications, Editors, Recording Secretary, Secretary and Corresponding Secretary, Tellers, Treasurer.

Reports of Annual Meetings.

Academy awards, Miscellaneous records of.

Records of academy delegates to scientific congresses, etc.

Correspondence in re publication of Proceedings of the Academy, 1901–1912.

Correspondence in re publication of Red Book.

Correspondence in re publication of JOURNAL.

Applications for affiliation of scientific societies and action taken thereon.

Membership lists.

Lists of past officers.

Formation and early history of the Academy.

Amendments proposed to bylaws.

Scientific societies of the Washington area (1936 questionnaire).

Committee reports, attendance at scientific meetings, Botanic Garden, honorary foreign memberships, executive, finance, JOURNAL, meetings, meeting places, membership, nominating, publication, miscellaneous.

Miscellaneous folders on District of Columbia, Kober lectureship, presentation of medals, directions for operating Hare system, American Association for the Advancement of Science, American Metric Association, popular books in science, engraving Academy notification forms.

Miscellaneous unsorted correspondence.

JOHN A. STEVENSON.

The President then announced the recipients of the Academy Awards for 1950 as recommended by the Committee on Awards for Scientific Achievement and approved by the Board of Managers:

Biological Sciences: DAVID H. DUNKLE, U. S. National Museum, in recognition of his distinguished service in paleontology, especially by researches on early arthrodiran and teleost fishes.

Engineering Sciences: SAMUEL LEVY, National Bureau of Standards, in recognition of his distinguished service in the structural analysis of aircraft.

Physical Sciences: PHILIP H. ABELSON, in recognition of his distinguished service in the fields of chemistry, nuclear physics, and in the physics of living organisms.

REPORT OF THE COMMITTEE ON MEMBERSHIP

During the Academy year, the Committee on Membership held six meetings and processed 124 nominations for membership. Seventy of these represented the physical sciences, 44 the biological sciences, and 10 the engineering sciences. One hundred and twelve of these nominations were for resident membership and 12 for nonresident. The scientific background and achievements of each nominee were abstracted and presented to the Board of Managers at its regular meetings.

The Chairman wishes to express his thanks to all the members of the committee for their kind cooperation in the work, and to the President, Secretary, and members of the Board for their many helpful suggestions.

ROGER G. BATES, *Chairman.*

REPORT OF COMMITTEE ON ENCOURAGEMENT OF SCIENCE TALENT

The Committee arranged for the participation of the Academy in the Ninth Science Talent Search of the Westinghouse Educational Foundation, as sponsor of the Second Annual Talent Search in the District of Columbia. In continuance of this custom the committee has also started preliminary work for the Tenth Science Talent Search.

Last year's search resulted in the recommendation by the committee of six local participants in the national search to the Academy's Board of Managers for the award of a Certificate of Merit from the Academy. The awards were presented by the Academy at its Annual Honors Meeting in March 1950. Letters of recommendation from the Academy for scholarship awards were sent to the universities of choice of the award recipients.

The Academy, through the medium of the committee, again sponsored the Annual Science Fair for local high and junior high school students, in cooperation with the Science Departments of the Public Schools of the District of Columbia. The fair was held May 15–19, 1950, in the lobby of the Department of Commerce Building, with 564 exhibitors selected from about 1500. Thirty-six winners were presented Certificates of Award by the President of the Academy, after selection by a group of judges from the Academy.

The expenses of the committee consisted of $115 representing the Academy's contribution to support the Fourth Annual Science Fair.

The membership of the Committee during the year was: DR. B. D. VAN EVERA; DR. A. T. MCPHERSON; DR. FRED MOHLER; AUSTIN H. CLARK; JOSEPH M. CALDWELL, and DR. M. A. MASON, Chairman.

MARTIN A. MASON, *Chairman.*

After acceptance by the members of the report read by the Chairman of the Committee of Tellers, the President declared the following individuals elected to the given offices:

WALTER RAMBERG, *President-Elect*
FRANCIS M. DEFANDORF, *Secretary*
HOWARD S. RAPPLEYE, *Treasurer*
SARA E. BRANHAM and JOHN A. STEVENSON, *Board of Managers to January 1954*

The following members of the Academy, nominated by the Affiliated Societies, were duly elected Vice-Presidents of the Academy:

Philosophical Society of Washington—EDWARD U. CONDON
Anthropological Society of Washington—WALDO R. WEDEL
Biological Society of Washington—[Vacancy]
Chemical Society of Washington—JOSEPH J. FAHEY
Entomological Society of Washington—FREDERICK W. POOS
National Geographic Society—ALEXANDER WETMORE
Geological Society of Washington—LEASON H. ADAMS
Medical Society of the District of Columbia—[Vacancy]
Columbia Historical Society—GILBERT GROSVENOR
Botanical Society of Washington—E. H. WALKER
Washington Section, Society of American Foresters—WILLIAM A. DAYTON
Washington Society of Engineers—CLIFFORD A. BETTS
Washington Section, American Institute of Electrical Engineers—FRANCIS M. DEFANDORF
Washington Section, American Society of Mechanical Engineers—RICHARD S. DILL
Helminthological Society of Washington—L. A. SPINDLER
Washington Branch, Society of American Bacteriologists—ANGUS M. GRIFFIN
Washington Post, Society of American Military Engineers—HENRY W. HEMPLE
Washington Section, Institute of Radio Engineers—HERBERT G. DORSEY
District of Columbia Section, American Society of Civil Engineers—[Vacancy]

The President introduced the speaker, PER K. FROLICH, Vice-President of Merck & Co. DR. FROLICH gave an illustrated talk on *Medicinal chemicals.* He outlined the various procedures followed in producing, under rigid requirements of purity, the various antibiotics, vitamins, and other life-saving chemicals. He reviewed the various steps required to produce these medicinal compounds, from the minute quantities obtained in the original fundamental research laboratories to the very large scale production of many tons per day. These operations require great team work on the part of many related disciplines.

The retiring President, F. B. SILSBEE, expressed his appreciation to the officers, to the Board of Managers, and to the various committee chairmen for their work and cooperation throughout the year. He then introduced the new President, NATHAN R. SMITH, who had served as President-Elect during 1950. After a few interesting remarks the new President adjourned the meeting at 10:15 P. M.

FRANK M. SETZLER, *Secretary.*